1976

An Evaluation of Diurnal Habitat Requirements for the American Woodcock (Philohela Minor Gmelin) in Southern Louisiana.

James Marshall Dyer
Louisiana State University and Agricultural & Mechanical College

76-25,260

DYER, James Marshall, 1946-
AN EVALUATION OF DIURNAL HABITAT REQUIREMENTS FOR THE AMERICAN WOODCOCK (*Philohela minor* Gmelin) IN SOUTHERN LOUISIANA.

The Louisiana State University and Agricultural and Mechanical College
Ph.D., 1976
Agriculture, forestry and wildlife

Xerox University Microfilms, Ann Arbor, Michigan 48106

AN EVALUATION OF DIURNAL HABITAT REQUIREMENTS FOR THE AMERICAN WOODCOCK (*Philohela minor* Gmelin) IN SOUTHERN LOUISIANA

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The School of Forestry and Wildlife Management

by
James Marshall Dyer
B.S., Oklahoma State University, 1969
M.S., Oklahoma State University, 1973
May, 1976

ACKNOWLEDGEMENTS

Research funds for this project were provided through the Agricultural Experiment Station of Louisiana State University.

Dr. R. B. Hamilton served as my major professor and his advice and counsel are deeply appreciated.

The members of my graduate committee, Dr. R. H. Chabreck, Dr. L. L. Glasgow, Dr. G. H. Lowery, Jr., and Dr. B. A. Thielges provided valuable assistance throughout the study. I am grateful to Mr. J. D. Newsom of the Louisiana Cooperative Wildlife Unit for his assistance with securing landowner cooperation and for providing various materials necessary for the completion of this project. I would also like to thank Dr. P. E. Schilling for his assistance with the research design and statistical analyses portions of this study; Dr. A. D. Oliver, Jr. for his assistance with insect identification; Dr. R. L. Miller for his assistance with seed identification; Dr. E. D. Roberts for his assistance with preparing and interpreting material used for eye analyses, and Mr. Mike Raymond for programming data for computer analysis.

Special thanks go to Dr. L. D. Newsom, for the use of his fine Brittany Spaniels, to Mrs. Babs Webb for her superb typing ability and to Professor A. B. Crow for his editorial advice.

I would also like to thank the landowners who allowed me to work on their land and in particular Mr. John Hess, who took an active interest in this study.

Although a list of all those workers who helped with the field work portion of this study would be too lengthy to include in this work, there were a few who deserve special thanks. Mr. James Simons, Mr. Kenneth Bailey, Mr. Thomas Hoffman, and Mr. Ben Gould frequently worked almost all night during some of the worst possible weather conditions.

Finally, I would like to thank my parents, Mr. and Mrs. J. E. Dyer, and Ms. Teegie Gaidry for their support during the course of this study.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
LIST OF TABLES	vii
LIST OF FIGURES	ix
ABSTRACT	xii
JUSTIFICATION AND SCOPE OF STUDY	1
DESCRIPTION AND SELECTION OF AREAS FOR STUDY	4
Geographical Area and Physiography	4
Vegetational Types and Land Use	5
Climate	6
Specific Sites Chosen for Study	7
Morganza (Area 1)	7
Bayou Choctaw (Area 2)	13
Grosse Tete (Area 3)	16
STUDY METHODOLOGY	20
Diurnal Habitat Evaluations	20
Collecting Woodcock	20
Measurement of Habitat Variables	21
Flushing Point Analyses	22
Eye Morphology	31
Sample Sources	32
Examination Techniques	32
Evaluation of Food Habits	33
Collection of Samples	33
Stomach Examinations	34
Volumetric analyses	34
Ingestion stages	34
Comparison with Flushing Sites	38

	Page
Local Movement Studies	38
Tagging Methods	41
Other Banding Efforts	42
Breeding Activity in Louisiana	42
Random Sample Analyses	43
RESULTS AND DISCUSSION	45
Diurnal Habitat	45
Soil Characteristics	45
Soil pH	49
Soil moisture	50
Litter depth	54
Vegetation Analyses	56
Vegetation frequency and coverage	57
Plants used for analyses	64
Comparisons of total vegetation on each area	76
Overstory Analyses	78
Other Site Analyses	83
Structural site components	84
Light as a site factor	88
Relationships between habitat and light intensities	92
Comparison of total flushes	113
Findings compared to similar studies	117
Summation of Site Factors	124
Eye Analyses	125
External Features	126
Internal Features	130
Food Habits	136
Amounts of Foods	136
Previous studies pertinent to feeding intervals	143

	Page
Conclusions regarding amounts and frequency of feeding	146
Types of Foods	147
Types of food reported in previous studies	164
Conclusions regarding types of foods	168
Relationship of Food Items to Habitat	168
Local Movements in Response to Climatic Changes	175
Breeding Activity	184
Nesting Activity	184
Testes Development	189
Testes development related to migration	195
ADDITIONAL OBSERVATIONS	196
CONCLUSIONS AND MANAGEMENT IMPLICATIONS	199
LITERATURE CITED	203
APPENDIX	210
VITA	213

LIST OF TABLES

Table		Page
1.	Results of t-tests comparing soil pH between random plots on two study areas, flushing points on three study areas, and between random plots and flushing points on two study areas	46
2.	Results of t-tests comparing soil moisture between random plots on two study areas, flushing points on three study areas, and between random plots and flushing points on two study areas	47
3.	Results of t-tests comparing litter depth between random plots on two study areas, flushing points on three study areas, and between random plots and flushing points on two study areas	48
4.	Vegetation sampled on 70 random milacre plots from two study areas	58
5.	Vegetation sampled on 202 flushing points from three study areas	60
6.	Mean percent coverage per plot and relative ranking of coverage of plant species on two study areas (both random plots and flushing points) and results of t-tests showing significant differences of coverage between plants on random plots versus flushing points	62
7.	Comparison of the frequency of occurrence of plant species on random versus sampled plots on two study areas by means of a Chi-square test and a Spearman rank correlation coefficient	77
8.	Results of t-tests comparing basal area of trees 9 inches dbh or larger on random plots with those on flushing points	79
9.	Comparison of overstory tree species sampled on random plots from two study areas and flushing points from three study areas	80
10.	Frequencies and percentages of each "type" on two study areas and results of a Chi-square test to analyze differences of distributions of "types" between flushing points and random plots	85

Table		Page
11.	Frequencies and percentages of each density value on random and sample plots and results on Analyses of Variance comparing densities between random plots and flushing points	87
12.	Results of t-tests comparing reflected light (in foot-candles) between random plots on two study areas, flushing points on three areas, and between random plots and flushing points on two study areas	90
13.	Percent of total available reflected light at random plots and woodcock flushing sites on three bottomland hardwood study areas	91
14.	Frequencies and percentages of flushes (according to vegetational types under periods of bright light and low light) and results of a Chi-square test comparing the two distributions	114
15.	Comparisons of the composition of the retinae of three avian species	135
16.	Least squares analysis of variance to test the effect of time of collection and digestive stage on stomach volume	140
17.	A comparison of invertebrates taken from 677 woodcock stomachs, 202 points from which woodcock were flushed, and 70 random plots	170
18.	A comparison of seeds taken from 677 woodcock stomachs, 202 points from which woodcock were flushed, and 70 random plots	172
19.	Food items that had significantly different distributions on flushing points than for random plots	174
20.	Dates and locations of returns of backtags affixed to woodcock in southern Louisiana	177
21.	A comparison of the average temperature and daylight sky coverage for the two winters in which woodcock were collected in southeast Louisiana	194
22.	Plants sampled from 202 woodcock flushing sites on three bottomland hardwood study areas in south-central Louisiana	211

LIST OF FIGURES

Figure		Page
1.	Location of the three areas used in this study.......	8
2.	Aerial photograph of Study Area No. 1, Morganza, Louisiana (photographed in 1971)....................	11
3.	Aerial photograph of Study Area No. 2, Bayou Choctaw, Louisiana (photographed in 1969)....................	14
4.	Aerial photograph of Study Area No. 3, Grosse Tete, Louisiana (photographed in 1971)....................	18
5.	Type 1 flushing site: Switch-cane thicket..........	24
6.	Type 2 flushing site: Blowdown.....................	25
7.	Type 3 flushing site: Blackberry-dewberry thicket...	26
8.	Type 4 flushing site: Hardwood understory..........	27
9.	Type 5 flushing site: Fencerow.....................	28
10.	Type 6 flushing site: Honeysuckle thicket..........	29
11.	Type 7 flushing site: Greenbrier thicket...........	30
12.	Equipment used for capturing woodcock at night.......	35
13.	Method of collecting woodcock for food habits analyses...	36
14.	Sample of stomach contents that were designated as an "early" digestion stage............................	37
15.	Sample of stomach contents that were designated as an "intermediate" digestion stage......................	39
16.	Sample of stomach contents that were designated as an "advanced" digestion stage..........................	40
17.	Distribution of woodcock flushes over a 3 year period on Area 1 (Morganza) during periods of bright external light..	93
18.	Distribution of woodcock flushes over a 3 year period on Area 1 (Morganza) during periods of low external light..	95

Figure		Page

19. Vegetational types (by percent) on Area 1 (Morganza) and a comparison of flushes during high and low light intensities for each vegetational type.............. 98

20. Distribution of woodcock flushes over a 3 year period on Area 2 (Bayou Choctaw) during periods of bright external light.................................... 100

21. Distribution of woodcock flushes over a 3 year period on Area 2 (Bayou Choctaw) during periods of low external light...................................... 102

22. Vegetational types (by percent) on Area 2 (Bayou Choctaw) and a comparison of flushes during high and low light intensities for each vegetational type..... 104

23. Distribution of woodcock flushes over a 3 year period on Area 3 (Grosse Tete) during periods of low external light... 107

24. Distribution of woodcock flushes over a 3 year period on Area 3 (Grosse Tete) during periods of low external light... 109

25. Vegetational types (by percent) on Area 3 (Grosse Tete) and a comparison of flushes during high and low light intensities for each vegetational type.............. 111

26. A flushing site sampled when the external light level was 17.5 foot-candles............................. 115

27. A flushing site sampled when the external light level was 4.1 foot-candles.............................. 116

28. A comparison of the size of the eyes of a Bobwhite and an American Woodcock............................. 127

29. A section of the retina of the American Woodcock photographed at 100X magnification...................... 132

30. A section of the retina of the Bobwhite photographed at 100X magnification............................. 133

31. A section of the retina of the Chuck-will's-widow photographed at 100X magnification.................... 134

32. Mean stomach volumes of woodcock collected at hourly intervals... 138

Figure		Page
33.	Mean digestive stages of woodcock stomachs collected at hourly intervals................................	141
34-45.	Percentage frequency of 12 food items in woodcock stomachs at hourly intervals........................	149-160
46.	Mean hourly numbers of four types of invertebrates commonly found in woodcock stomachs.................	162
47.	Total contents of woodcock stomach No. 231; bahia grass seeds, smartweed seeds, and curly dock seeds..	165
48.	A comparison of flushes-per-man-hour in nocturnal fields to temperatures for the winter of 1971-72....	178
49.	A comparison of flushes-per-man-hour in nocturnal fields to temperatures for the winter of 1972-73....	180
50.	A comparison of flushes-per-man-hour in nocturnal fields to temperatures for the winter of 1973-74....	182
51.	Distribution of 221 nesting reports in Louisiana for a 27 year period.................................	186
52.	Habitat surrounding a woodcock nest located 12.7 miles north of Baton Rouge, Louisiana....................	188
53.	A comparison of the volume of testes collected from woodcock during the spring months of 1970, 1971, and 1972 in Maine and from woodcock collected during the winters of 1972-73 and 1973-74 in Louisiana.........	191

ABSTRACT

Research aimed at analyzing variables that constitute or affect diurnal habitat for American Woodcock (Philohela minor) was conducted in southeastern Louisiana over a 3-year period. Three bottomland hardwood timber tracts with open, agricultural fields nearby were used for study.

Woodcock were found to inhabit diurnal sites that have significantly higher soil moisture, significantly less litter, and denser vegetation than "typical" or random sites in bottomland hardwood habitats. Significant differences existed between plant communities associated with sites from which woodcock were flushed and those associated with randomly distributed plots. The typical understory plant composition associated with the average flushing sites consisted of plants that grow in dense aggregations such as switch-cane (Arundinaria gigantea), blackberry or dewberry (Rubus spp.), and Japanese honeysuckle (Lonicera japonica). The overstory associated with a typical flushing site consisted of denser, smaller, more moisture tolerant tree species than did the randomly selected sites.

Light reduction was the most consistent habitat variable studied. All flushing sites analyzed had a relatively constant light intensity regardless of the magnitude of external light, thereby emphasizing the need for a diversity of floral types and forms in order to make a habitat attractive to woodcock. Although flushes were associated with plant species that grow in thick aggregates, these aggregates had to possess less dense portions in order to create habitat during all daylight time

periods and during all conditions of cloud coverage. A morphological examination of the woodcock eye also suggested the importance of light intensity for determining woodcock habitat. By comparing the woodcock eye to the eyes of both diurnally and nocturnally oriented birds, this study showed that the woodcock eye can probably function adequately in fairly bright light, but is undoubtedly more efficient under conditions of relatively low light.

The food habits of woodcock on the wintering grounds were investigated and the species was found to be an opportunistic feeder. Because no difference was found between food items collected from random plots and points from which woodcock were flushed; because the types of foods consumed changed with the habitats occupied; and because no correlation existed between types of foods eaten on each of the three study areas during the same time periods, the consumption of food was interpreted as being incidental to the habitat occupied. In other words, the habitat was chosen or occupied on the basis of some factor other than food. Another phenomenon observed during the food habits analysis was a periodicity of feeding. Woodcock were found to feed twice in diurnal cover and once in nocturnally-used fields. Contrary to the opinion of some previous authors, this study suggests that feeding may not be the sole purpose for occupying open fields at night. Considering the strength of woodcock scent, desertion of wooded areas in favor of open areas, where visibility is good, may have a survival advantage in terms of escaping mammalian predation.

Local movements were studied by marking birds with back-tags. A definite southward movement in response to cold weather and a possible northward movement in response to warm weather was identified. By counting numbers of birds in nocturnally-used fields, I found that the timing and intensity of migrations are probably influenced by climatic conditions.

The analyses of reproductive activity indicated that nesting is probably quite common in north Louisiana. The incidence of females carrying eggs during the hunting season in Louisiana was relatively rare. Testes development was shown to be affected by climatic changes on the wintering ground and possibly could be beneficial for predicting migration times or breeding periods.

JUSTIFICATION AND SCOPE OF STUDY

The American Woodcock (Philohela minor) is something of an oddity in the avifauna of North America. Although a shorebird, the woodcock has become adapted to residing diurnally in a forested environment and nocturnally in open areas such as pastures, harvested croplands or burned-over timber lands. It possesses some unique morphological characteristics that maximize the benefits of this type of life style. Some of the most apparent of these anomalous characteristics include an enlarged eye that aids in upward and rear vision, a camouflage coloration that matches the pattern and color of most forest litter, and a long, movable bill capable of probing for subterranean food items as well as picking up foods from the ground surface. Behaviorally, this species has also diverged from most Charadriiformes and has adopted characteristics favorable to its type of life. The use of clearings in wooded areas for the distinctive breeding flight is advantageous to mating efforts for a species that normally occupies areas where visibility is restricted by rank vegetation. The trait of sitting motionless or "freezing" when approached maximizes the benefits of its protective coloration. From an ornithological viewpoint, the study of morphological and ethological responses to evolutionary pressure on this species would be intriguing.

Most studies of this bird, however, have involved analyzing factors related to management of the woodcock as a hunting resource. Since this species exhibits such attributes as "holding" before hunting dogs, erratic flushing and flight behavior, and excellent table fare, it is considered a game bird and has been the subject of extensive study in terms of population dynamics, habitat manipulation, and hunting pressure measurements. Most of these studies have been done on the breeding grounds in Pennsylvania, Michigan, Maine, and other northeastern states. A majority of the studies done on the wintering grounds have involved capturing and banding woodcock and using band return information to derive population indices or analyze migration patterns. Only a few studies have been conducted on the wintering grounds that emphasized diurnal habitat analysis. This lack of study is possibly due to the difficulty presented by working in the thick vegetation and swamp environments which usually comprise diurnal cover in the southern states. Also, the comparatively low priority placed on woodcock as a game resource in the southeast may serve as an impairment to habitat research.

A considerable amount of diurnal habitat for wintering woodcock consists of bottomland hardwood areas. Because these areas tend to be very fertile, they are rapidly being cleared of timber and planted to agricultural crops. The effects of this clearing on the wintering woodcock population are virtually unknown because of the lack of knowledge of precise diurnal habitat requirements. This same lack of knowledge would hamper any efforts to manage habitat for wintering woodcock. Research efforts to analyze diurnal habitat are therefore worthwhile and appropriate. Hopefully, this study will contribute to that cause.

This study was initially a continuation of research begun in 1969 that was intended to emphasize population dynamics of woodcock wintering in south-central Louisiana. The evaluation of diurnal habitat was one of three major objectives of this study when it began in 1971. However, the need for comprehensive habitat research became apparent during the first year of study and the project was modified to specifically emphasize diurnal habitat evaluations. The determination of the type and amount of use of diurnal habitat utilized by wintering woodcock in southern Louisiana then became the primary objective of the study.

The plan of study necessitated an initial identification of environmental variables before methods could be devised to analyze them. Exploratory sampling began in 1971 to attempt to identify the variables that would warrant further study. The winters of 1972, 1973, and 1974 were then spent sampling these variables.

Although the main purpose of the study was an analysis of diurnal habitat, I felt that certain aspects of woodcock behavior were inseparable from the study of habitat requirements. Such factors as local migrations in response to weather changes, or the relationships between occupancy of nocturnally-used fields and diurnal cover were incorporated into the study, these had considerable impact on the choice of diurnal cover by woodcock. I analyzed several other behavioral traits such as feeding habits, daily movements, and reactions to certain environmental stimuli in regard to their influence on diurnal habitat selection.

While gathering data for habitat analyses, I investigated several avenues of study that warrant separate mention. In an effort to evaluate habitat selection from a physiological viewpoint I made a morphological comparison between the woodcock eye and the eyes of two other avian species. Also, I collected data on the breeding behavior of woodcock in Louisiana with special emphasis on testicular alterations in response to seasonal weather changes.

DESCRIPTION AND SELECTION OF AREAS FOR STUDY

Glasgow (1958) indicated the Avoyelles, St. Landry, Iberville, and Point Coupee parishes were the chief wintering areas for woodcock in Louisiana. Therefore, these parishes were the ones considered for sampling in diurnal habitat. A previous study by Britt (1971) utilized areas in both Point Coupee and Iberville parishes and one of these was deemed acceptable for use in this study. Two other areas were chosen by studying aerial photographs, consulting local biologists and other informed sources and by a series of preliminary observations.

Geographical Area and Physiography

The areas used for study were located in the center of the Gulf Coastal Plain Physiographic Province (Fenneman 1938). All of the study areas were on the west side of the Mississippi River, within 20 miles of the most recent Meander Belt. This area is generally referred to geologically as a backswamp area and alluvium deposits are from 100 to 120 feet deep (Saucier 1974). The extensive backswamp environment in this area is a result of the position of the most recent meander belt on the western edge of the alluvial valley between what is now Baton Rouge, Louisiana, and Lafayette, Louisiana. The southern portion of this valley between the Atchafalaya River and the Mississippi River represents the largest backswamp in this region and is commonly referred to as the Atchafalaya Swamp (Fisk 1952). About 12,000 years ago the Mississippi River in this area changed from a braided to a meandering regimen and started forming some of these backswamps (Kinitzsky and Smith 1969). During this period, the average floodplain level was 75 to 80 feet lower than it is now (Saucier 1974).

All of these backswamps were areas of overbank deposition and the soils are deep and fertile. The soil types of this area are mainly Mhoon, a clay loam; Commerce, a silt loam; and Sharkey, a clay. These soils are frequently flooded; but when soil moisture is low, they become very hard. Other soil types that have been identified from this general area include Iberia, Dundee, Baldwin, Tunica, and Cypremont (Lytle 1968).

Vegetational Types and Land Use

The timbered portions of the study areas were all of a foodplain timber type commonly referred to as bottomland hardwoods. The major species of trees found in these areas were sugarberry (*Celtis laevigata*), bitter pecan (*Carya aquatica*), water oak (*Quercus nigra*), willow oak (*Quercus phellos*), Nuttall oak (*Quercus nuttallii*), cherrybark oak (*Quercus falcata* var. *pagodaefolia*), sweetgum (*Liquidambar styraciflua*), boxelder (*Acer negundo*), American elm (*Ulmus americana*), honey locust (*Gleditsia triacanthos*), and swamp red maple (*Acer rubrum* var. *drummondii*).

Commonly occurring species of lesser vegetation included dogwood (*Cornus sp.*), deciduous holly (*Ilex decidua*), switch-cane (*Arundinaria gigantea*), palmetto (*Sabal minor*), water elm (*Planera aquatica*), haw (*Crataegus sp.*), and blackberry and dewberry (*Rubus* spp.). Some of the common vines were greenbrier (*Smilax* spp.), poison ivy (*Toxicodendron radicans*), rattan-vine (*Berchemia scandens*), and cross-vine (*Anisostichus capreolata*).

The study areas also were comprised of fields used for agricultural purposes such as the farming of soybeans (Glycine max), sugarcane (Saccharum sp.), and cotton (Gossypium hirsutum) or as pasturelands for livestock. Although agriculture is an important activity in Iberville and Point Coupee parishes, timber production and oil are the most economically important resources. The timber in this area is being cleared at a rapid rate and the land is being converted to soybean fields or pastures (Yancey 1969). Oil production in this area is high, especially in northeast Iberville parish. Petroleum exploration commonly occurs throughout both parishes and this exploration and its associated activities usually result in substantial vegetational changes. An abandoned road or oil well drilling site will usually produce vegetation typical of a natural ridge within a bottom. Because these ridges are not subjected to the flooding intensity of the bottoms, tree species that prosper on dryer sites are found. These areas are frequently invaded by very dense growths of blackberry or dewberry and are often virtually impenetrable.

Climate

Diurnal habitat evaluations were conducted in south central Louisiana during November, December, January, and February of 1970, 1971, and 1973. This part of Louisiana is considered to be subtropical and the temperatures are somewhat moderated by the Gulf of Mexico which provides warm, southerly winds. Average temperature for the month of November for the 3 years of this study was 56.99^{o}F, December averaged 57.99^{o}F, January averaged 52.44^{o}F, and February averaged 53.99^{o}F (U. S. Dept. of Comm., 1970-73).

Specific Sites Chosen for Study

Three specific areas were chosen for study, each of which consisted of a nocturnal-use field and an associated tract of diurnal cover.[1] Several criteria were used for selecting each site, including: each study site had to be accessible during wet winter months; landowner cooperation had to be assured; and suitable diurnal cover had to be in close proximity to nocturnal-use fields. The three areas chosen for study were Morganza, Bayou Choctaw, and Grosse Tete (Fig. 1).

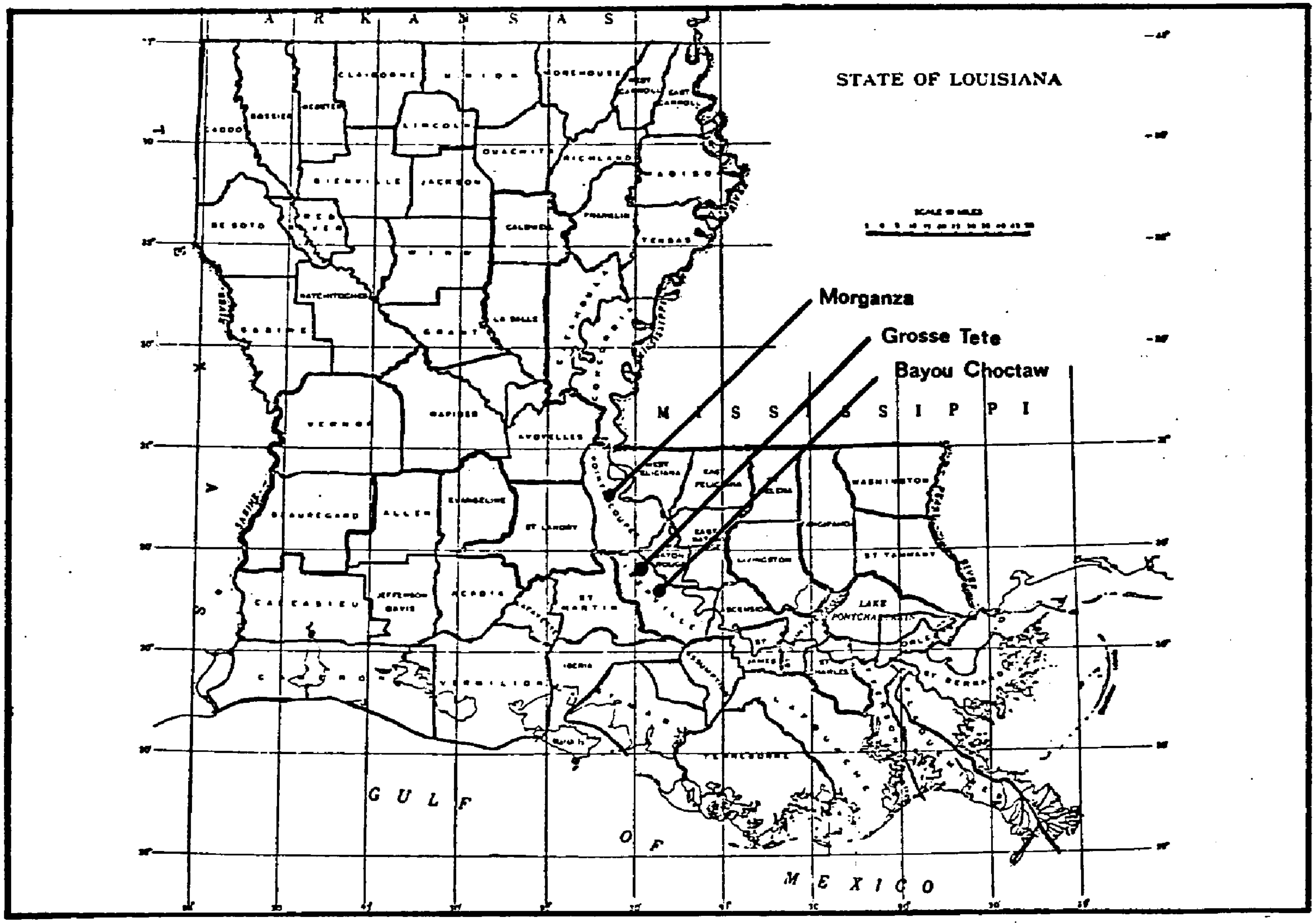
Morganza (Area 1)

This area is located at latitude 30°48' N. and longitude 91°40' W. in Point Coupee Parish, Louisiana. It is 6 miles south of Highway 1 where it crosses the Morganza Floodway levee. It is situated immediately west of the levee and is therefore out of the floodway system. The nocturnal-use fields were of two types. One type was a 198-acre wheat (*Triticum aestivum*) field which was used as winter pasture for cattle and the other type was composed of two small cotton fields, one of 1.9 acres and the other of 6.4 acres. The wheat field was traversed by several small drainage systems and two larger creeks. The drainage systems were where most of the woodcock were taken at night as the wheat field probably did not contain dense enough vegetation to be attractive to woodcock. The cotton fields were excellent nocturnal-use fields once the stalks were chopped.

---

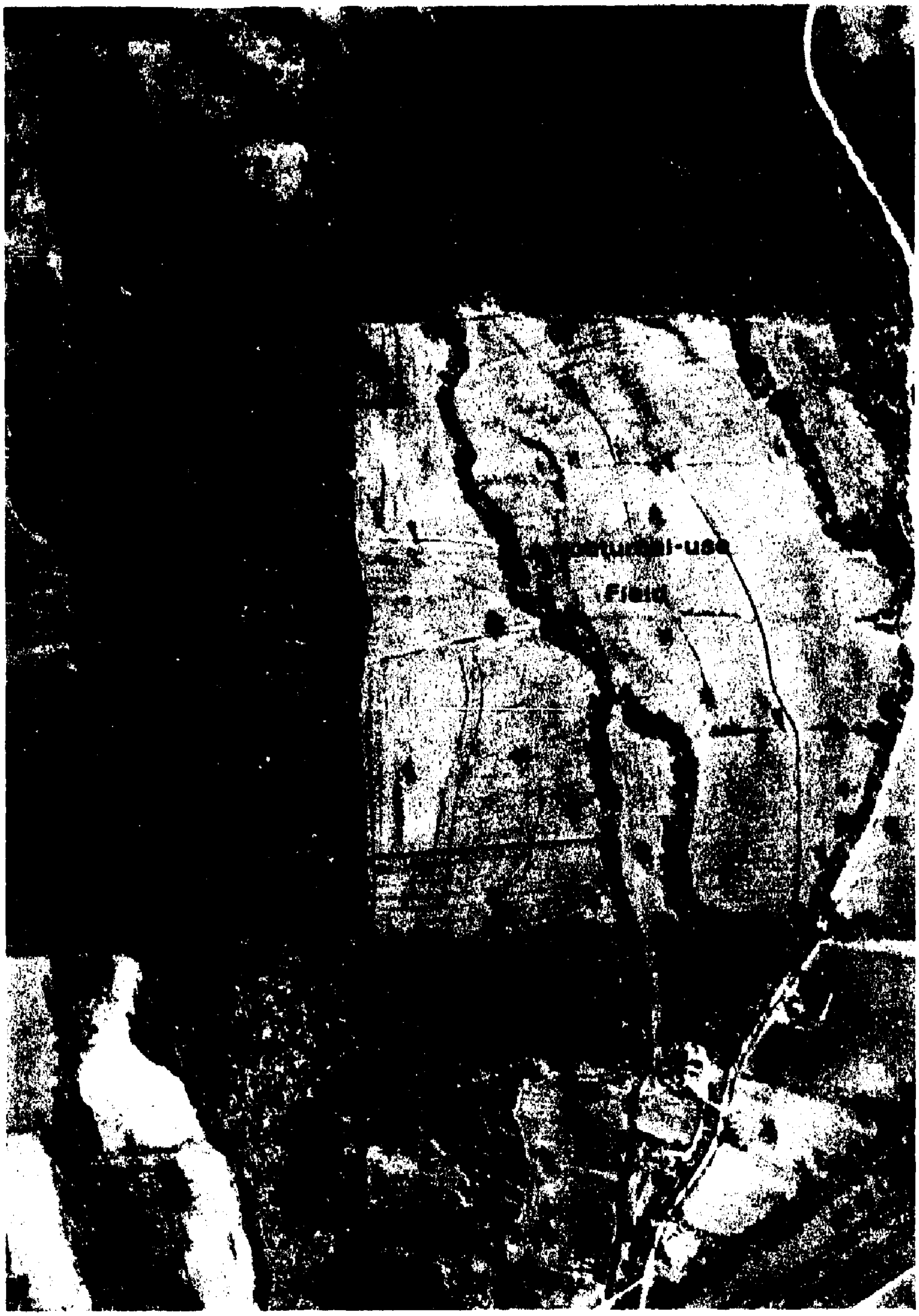
[1] Henceforth, nocturnal will be used when reference is made to those open, agricultural fields studied during nightly intervals and diurnal will be used to describe those forested habitats studied during the daylight hours.

Figure 1. Location of the three areas used in this study.


STATE OF LOUISIANA
A R K A N S A S
M I S S I S S I P P I
Morganza
Grosse Tete
Bayou Choctaw
G U L F
O F
M E X I C O

The diurnal cover associated with the nocturnal-use field was of two parts (Fig. 2): one was a 30-acre tract on the south side of the wheat field and the other was a 10-acre tract on the west side of the wheat field. Cattle were permitted to graze on the west tract but were fenced out of the south tract, making the understory of the west tract less dense. This area is within the original floodplain of the Mississippi River; however, since the construction of the Mississippi River levee system, the river no longer floods this area. There is a flood control levee one-quarter mile east of the study area. This levee is part of the Morganza Floodway Structure, which is designed to divert flows out of the Mississippi River during periods of extremely high water. Although this levee prevents the area from becoming completely inundated, heavy winter rains often result in a considerable amount of standing water on the study area because the levee prevents the water from flowing into the natural drainage system. The timber sampled was representative of that normally found on a fertile secondary terrace. Few large trees exist because of logging operations carried out about 30 years ago. Common tree species found in this area were water oak, willow oak, sweetgum, hackberry, American elm, boxelder, and several species of hickory. The smaller tree or shrub species commonly found on the area were swamp dogwood (*Cornus drummondii*), deciduous holly, yaupon holly (*Ilex vomitoria*), and swamp privet. Other lesser vegetation included blackberry or dewberry, greenbrier, poison ivy, cross-vine, and rattan-vine. Of particular note in this area were the extensive thickets of switch-cane. Some of these thickets were one-half acre or more in size.

Figure 2. Aerial photograph of Study Area No. 1, Morganza, Louisiana (photographed in 1971).


-use
Field

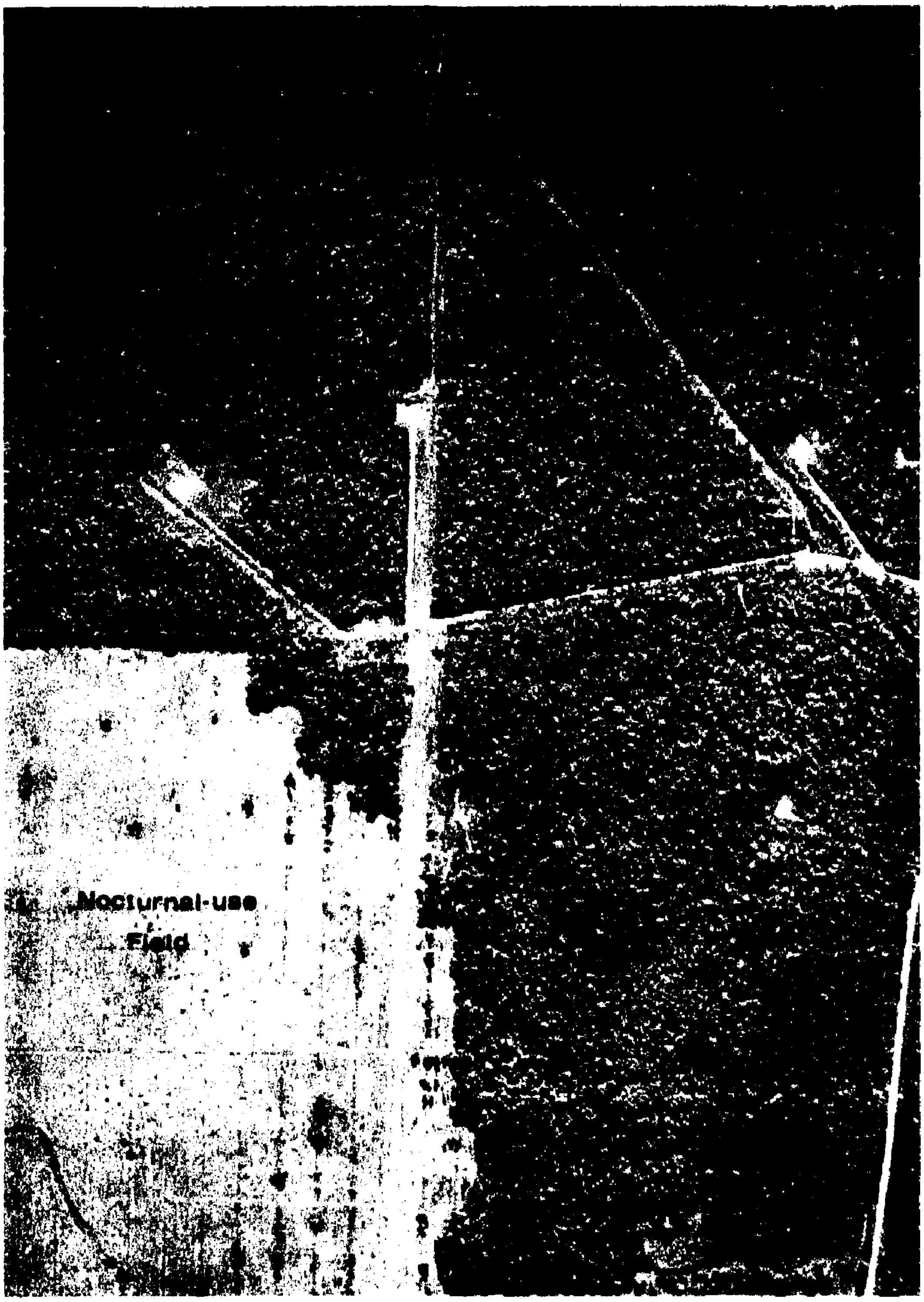
Bayou Choctaw (Area 2)

This area is located at latitude $30^{\circ}15'$ N. and longitude $91^{\circ}21'$ W. in Iberville Parish, Louisiana. It is in township 9S, Range 11E, in the northeast portion of Iberville Parish. The nocturnal-use field was a 237-acre field which was used primarily as pasture for cattle. This field was moderately grazed and contained smut grass (*Sporobolus poiretii*) and Dallis grass (*Paspalum dilatatum*) as the major grass species while Yankee weed (*Eupatorium capillifolium*), cocklebur (*Xanthium commune*), and sumpweed (*Iva ciliata*) formed the majority of the larger plant species observed. This pasture had several small drainages and these were frequently the areas of the highest woodcock concentrations. The attractiveness of this field to woodcock was apparently dependent on the intensity of grazing. During the winter of 1970-71, the landowner kept only a few cattle in this pasture and the vegetation grew very dense. Few woodcock used this area during that year. During 1972-73, the grazing was more intense, the vegetation less dense, and woodcock usage greater.

The diurnal cover associated with the nocturnal-use field was a 40-acre tract running along an oil field road (Fig. 3). This land is leased from the owner for oil and natural gas exploration and production. There are also several large underground pipelines passing through the area and the right-of-ways for the pipelines are kept free of timber so that they may be aerially inspected. Herbaceous and shrubby vegetation grows prolifically in these right-of-ways and is mowed periodically.

The diurnal cover was on a primary terrace of the Mississippi River and was of a wetter nature than the other two study areas. During most

Figure 3. Aerial photograph of Study Area No. 2, Bayou Choctaw, Louisiana (photographed in 1969).


Nocturnal-use
Field

of the winter months there was some standing water in the area. The timber in this area was characteristic of bottomland hardwoods. Water oak, willow oak, hackberry, American elm, bitter pecan, and red maple were commonly found. Some of the timber was logged about 30 years ago and few large trees remain. The understory vegetation was typified by greenbrier, blackberry, dewberry, swamp privet, palmetto, buttonbush, rattan, and poison ivy. Several areas were opened in the timber stand by oil company activities. These openings, if vacated, usually resulted in large blackberry and dewberry thickets which sometimes reached two acres or more in size.

Cattle were allowed to graze in these wooded areas; however, most grazing was confined to the pipeline clearings and the understory of the timbered lands was not substantially affected.

Grosse Tete (Area 3)

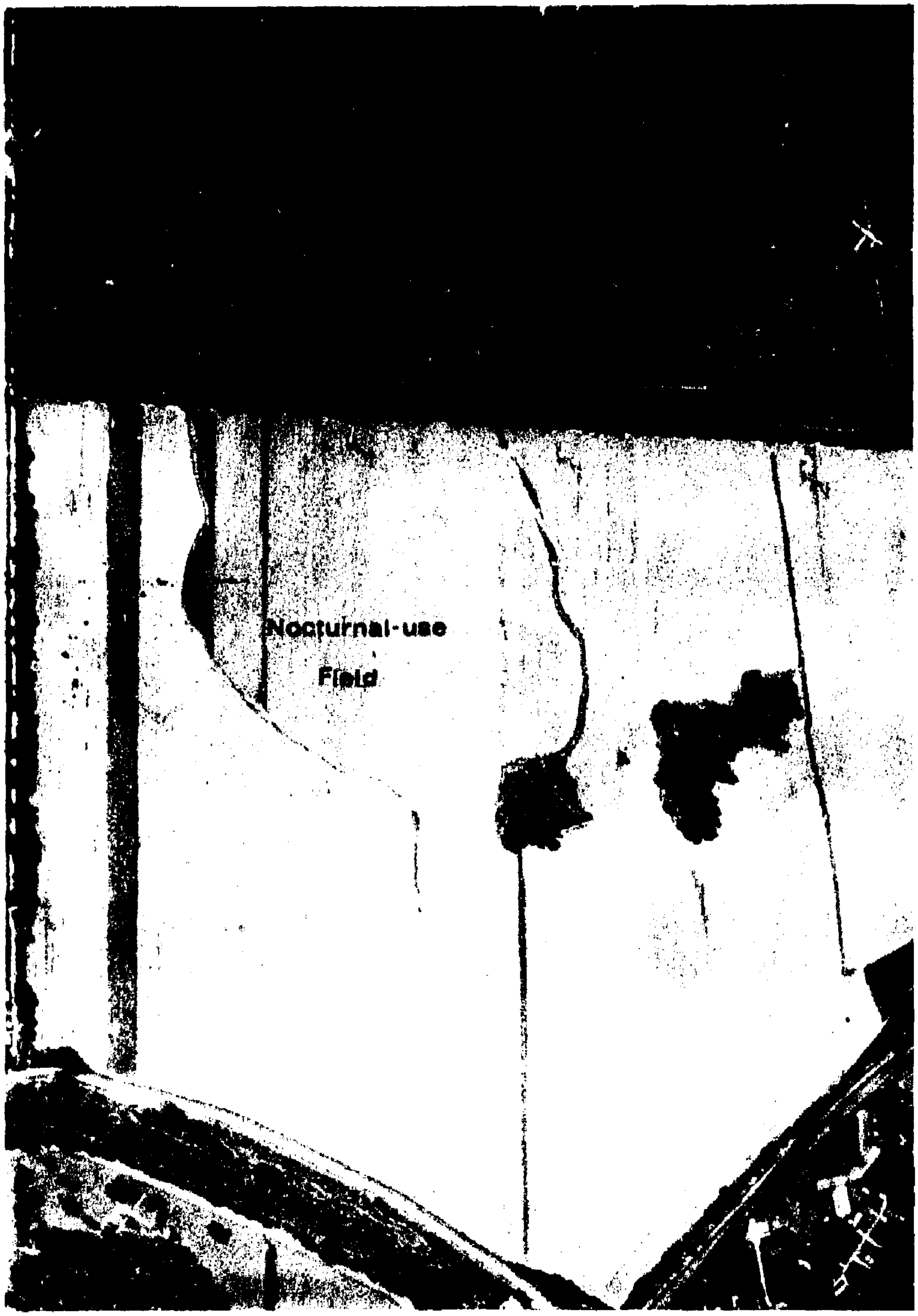
This area is located at latitude 30°21' N. and longitude 91°26' W. in Iberville Parish, Louisiana, about 0.5 mile south of the town of Grosse Tete. The nocturnal-use field was a 320-acre sugarcane field which was usually harvested during October. This field had several drainage systems traversing it and these small drainages provided moist areas even during periods of low rainfall. These drainages were usually the most productive areas for collecting woodcock at night unless the rainfall was sufficient to flood them.

The agricultural practices conducted by the landowner left the field in an ideal condition in terms of cover density as described by Glasgow (1958). However, several areas were rendered unsuitable to woodcock in late November and early December by the rank growth of

Senecio (Senecio glabellus). This plant appears soon after the sugarcane harvest in most fields in this area and it sometimes becomes so thick that the ground cannot be seen through the vegetation.

The associated diurnal cover was on the west side of the sugarcane field (Fig. 4). This 40-acre area was part of a lease from the owner by a hunting club. Cattle were allowed to graze in this area as were a few feral pigs so that the understory was kept somewhat open. This area is typical of a secondary terrace composed of fertile, alluvial soils which undergo periodic flooding during the winter and are fairly dry during the summer. The timber observed in this area was characteristic of a stand of bottomland hardwoods. However, the stand had been partially cut about 25 years ago so that few large trees remained. Water oak, willow oak, Nuttall oak, sweetgum, hackberry, bitter pecan, red maple, honey locust, American elm, and boxelder were the major tree species found in this area. Along the creeks and lower drainages, baldcypress (Taxodium distichum), and tupelo gum (Nyssa aquatic) were found. Shrub species found in the understory were rough-leaved dogwood, deciduous holly, haw, buttonbush (Cephalanthus occidentalis), and swamp-privet (Forestiera acuminata). Some of the lesser vegetation commonly found in the understory included greenbrier, blackberry, dewberry, switch-cane, rattan, cross-vine, poison ivy, and palmetto.

Figure 4. Aerial photograph of Study Area No. 3, Grosse Tete, Louisiana (photographed in 1969).


Nocturnal-use
Field

STUDY METHODOLOGY

Diurnal Habitat Evaluations

During the months of November, December, January, and February of 1971, 1972, 1973, and 1974, each of the three study areas was visited approximately once a week. This rate of visitation was hopefully infrequent enough to prevent severe disturbance to woodcock yet often enough to monitor population changes within each area.

In order to be able to classify types of cover utilized by woodcock, each study area was divided into five belt transects 40 surveyor chains long by 2 surveyor chains wide. Thus, each transect was 80 square chains or 8 acres. The boundaries of each transect were marked with flagging tape at 100-foot intervals. General vegetation characteristics such as thickets or openings were located and maps of each area were made showing these features. Dividing each study area into transects made the task of locating specific sites much easier. The use of transects was also beneficial for sampling each portion of each study area with equal frequency. By regularly varying the sampling sequence of the transects of each sampling period, bias associated with time was reduced.

Collecting Woodcock

Woodcock were located in their diurnal cover with bird dogs. Dogs were essential to thoroughly search all cover within the study areas. I found that two dogs worked more efficiently than one; however, the dogs had to be very well trained to stay within sight at all times. Of five breeds of dogs used in this study, I found Brittany Spaniels to be the best woodcock dogs and Shorthair Pointers to be the least effective. One of the inherent difficulties of this study was keeping the dogs within each specific transect. Often the dogs would wander into the adjacent transect and locate woodcock, which made record keeping difficult. Two study areas originally selected had to be abandoned due to hunting pressure. The three areas that were used were privately owned and were posted. As far as the author knows, no hunting occurred on any of the three study areas during the course of the study.

Once a woodcock was located, it was flushed and collected with a shotgun. The exact point from where the bird flushed could almost always be located by the "chalkings" (droppings left as the bird flushed). The behavior of the dogs revealed that woodcock sometimes moved up to 200 yards before flushing. When woodcock were believed to have moved, an effort was made to locate the original resting place of the bird. If this effort was unsuccessful, the flushing point information was discarded.

Measurement of Habitat Variables

At each flushing point, 6 measurements were made that were designed to analyze factors that might govern the choice of cover by woodcock. These measurements included a vegetational analysis, litter sample, soil moisture, soil pH, measurement of light at the flushing site as well as the level of direct sunlight, and a soil sample which was analyzed for food items. Also, every flushing point was marked with coded flagging tape and carefully recorded on a cover map. Records were maintained of the temperature and precipitation each time an area was visited.

Flushing Point Analyses

I used a 1/100 acre circular plot to analyze overstory plant species and a 1/1000 acre (milacre) plot to sample the midstory and understory plants. These plots had the same center point, which was the point from which the woodcock was flushed. I recorded the size, number, and species for all trees larger than 6 inches dbh (diameter at breast height). Analysis of the milacre plot consisted of dividing the plot into four equal parts by running two imaginary perpendicular lines (3.7 feet long) through the plot so that they crossed at the midpoint, thereby forming four equal sections. Each plant species that occurred within the plot was recorded and a percent coverage value was determined by counting the number of quarter sections in which it occurred. Thus, if a plant species was found in one of the quarter sections, its coverage percent was 25 percent. If it was found in two of the quarter sections, its coverage percent was 50 percent, and so on. This sampling technique represents a modification of the Aldous Deer Browse Survey Method (Aldous 1944). The Aldous technique was designed to measure the extent of utilization of certain plant species as food items for deer. However, the original technique relied upon ocular estimates of the percentage of the plot that was covered by a particular plant. By dividing the plot into equal sections and counting the number of sections in which a plant species occurred, some of the human error innate to ocular estimates was reduced. Nomenclature of plant species was according to Radford et al. (1968) and Fernald (1950).

Concomittant to these measurements, each flushing point was classified as to vegetative "type" and density. The "type" described the flushing points in general terms and were as follows: Type 1 - switchcane thicket (Fig. 5), Type 2 - a blowdown (tree top, etc.) (Fig. 6), Type 3 - blackberry thicket (Fig. 7), Type 4 - hardwood understory (Fig. 8), Type 5 - fencerow (Fig. 9), Type 6 - honeysuckle thicket (Fig. 10), Type 7 - greenbrier thicket (Fig. 11). The density value was based on ocular estimates and each flushing point was given a value of 1, 2, or 3 depending upon whether the density was heavy, medium, or light. These classifications were efforts to more accurately describe each flushing site.

To measure the litter depth at the point from which a woodcock was flushed, a probe sectioned into quarter-inch sections was used. This probe was pressed through the litter until it contacted the soil layer. In very wet or muddy areas, the point where the top of the soil layer began became difficult to ascertain. Also, many of the flushing sites contained thick deposits of humus, which was not considered to be part of the litter.

I used an E.M. System Soil Tester to measure the soil moisture and soil pH. This device was found to be an excellent piece of equipment for this type of work. It requires no probes, diaphragms, or calibration. By merely inserting the probe end into the ground, soil pH can be read immediately and a soil moisture reading appears within 1 minute or less.

Some workers feel that the selection of cover by woodcock could possibly be governed by light intensity (Pettingill 1971). One subjective measure of cover is light reduction. I therefore used light

Figure 5. Type 1 flushing site: Switch-cane thicket.

Figure 6. Type 2 flushing site: Blowdown.

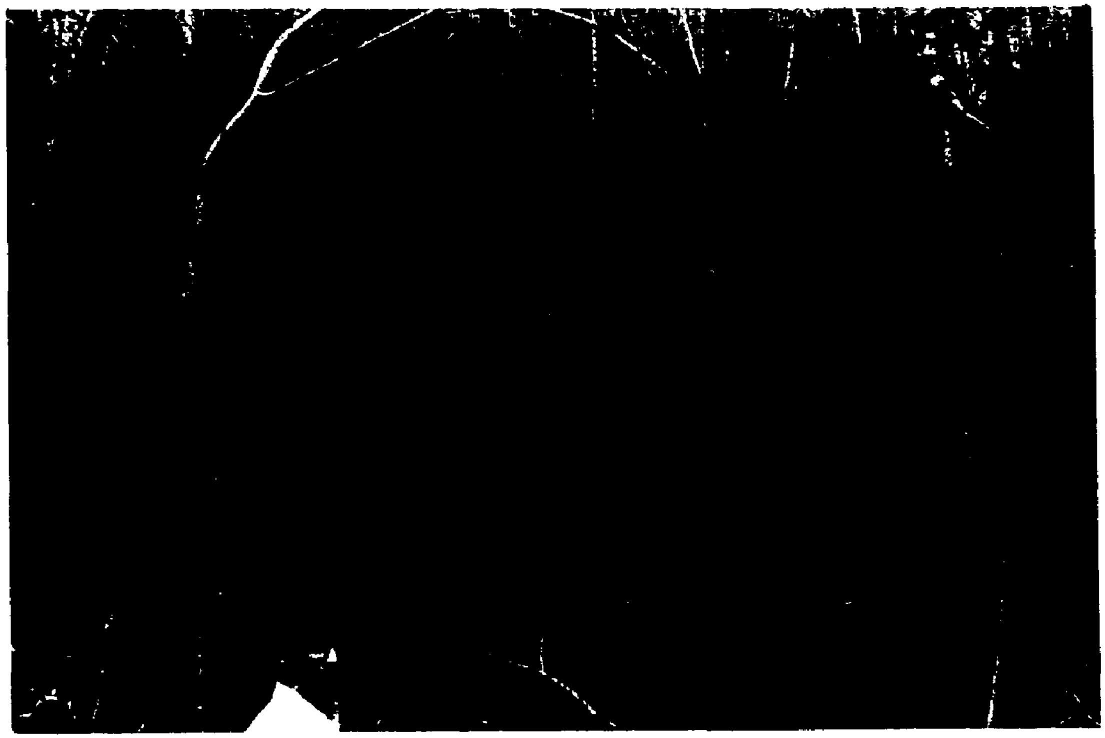


Figure 7. Type 3 flushing site: Blackberry-dewberry thicket.

Figure 8. Type 4 flushing site: Hardwood understory.

Figure 9. Type 5 flushing site: Fencerow.

Figure 10. Type 6 flushing site: Honeysuckle thicket.

Figure 11. Type 7 flushing site: Greenbrier thicket.

reduction as an indicator of cover density. To measure light intensities, a pair of Weston model XM-1 light meters were used. When a woodcock was flushed, the reflected light intensity in foot-candles at the flushing point was measured and a simultaneous reading was taken with the other light meter in an adjacent area receiving unobstructed sunlight. To obtain uniform readings and to nullify any differential background effect, I kept both light meters 1 foot above the ground and the sensor ends pointed downward and toward backgrounds of approximately the same color. The meters were uniformly calibrated so that when both light readings were obtained, a value for percent of available light could be directly calculated for the flushing point.

Eye Morphology

I investigated the eye structure as a possible indicator of habitat preference. As expressed by Pumphrey (1961): "Birds, of necessity, are eye-dominated and eye-dependent to a greater extent than any mammal, even the higher primates and man." It therefore seemed logical that studies of this organ might provide information relevant to habitat selection.

The woodcock eye is unique in several respects. First, the size of the eye is almost twice that of most other birds of comparable size. Allen (1925) believed this large size was an adaption for dusk or nocturnal feeding and noted that nocturnally-oriented birds often have large eyes. Waterman et al. (1971) pointed out that "nocturnal animals have large eyes with which to capture more light out of the dark; their eyes are efficient visual receptors for night vision." Another unique aspect of the woodcock eye is the location, higher on the head and more posterior than most avian species. The implications of this involve such things as better overhead vision, better night time vision and the ability to see toward the rear as well as toward the front.

Considering these external morphological features and the advantages they might provide in the type of habitat preferred by woodcock, it was thought that internal morphology might provide additional information on this subject.

Sample Sources

Sheldon (1967) noted that there have been no studies of the internal morphology of the woodcock eye and since information on this species was unavailable, I decided that a comparative approach would be best. Eye samples were taken from a Bobwhite (*Colinus virginianus*) and compared to woodcock eyes. This species was chosen because, like the woodcock, it is a ground-dwelling bird and is of comparable size to the woodcock. Also, eye samples were taken from a Chuck-will's-widow (*Caprimulgus carolinensis*), a species that is active during crepuscular or nocturnal periods and remains in dense thickets during the day, much the same as the woodcock.

Examination Techniques

I removed eyes from sacrificed specimens and immediately placed them in a 10 percent formalin solution. They were then placed in a Tissue Processor and treated with ethyl alcohol to remove water, then xylene to remove the alcohol. The whole eyes were placed in a parafin solution for impregnation and were frozen. When the tissues were hardened, cross-sectional cuts 2 to 5 microns thick were made across the retina. Care was taken to obtain the samples from the same area of the retina on all of the eyes. After the sections were cut they were stained with hematoxylin and eosin. The sections were then photographed at 63X and 100X magnification with varying exposures so that maximum clarity and contrast could be achieved.

Evaluation of Food Habits

Because feeding activity is often partly responsible for the habitat chosen by any species, I assumed that an investigation of diurnal habitat should include an analysis of food habits. To determine if food habits are indicative of habitat selection, food samples were taken at regular intervals. Interval sampling was the only way that trends in volume or types of food could be detected that might provide information about where a bird was feeding.

Collection of Samples

I collected samples at hourly intervals. Initially I felt that 40 woodcock should be collected during each of the hourly intervals. However this figure was later reduced to 20 per interval due to the amount of hunting pressure the initial collection regime would have imposed on the three study areas. The first 2 years of study were devoted to collecting birds in diurnal cover because I thought that the nocturnal sampling could be accomplished in one year. The reasoning for this was that it is much easier to collect birds in nocturnal fields than in diurnal habitat. However, during the final year of study (1973-74), the wintering population of woodcock in the areas of study was not as high as previously experienced. As a result, some of the nocturnal intervals were not sampled as intensively as planned although all intervals were represented by at least 15 woodcock.

Nocturnal collections were made with a net and headlight (Glasgow) 1958) (Fig. 12) or with a .22 caliber rifle with "rat shot" (Fig. 13) if the area was sufficiently isolated from habitation. I made collections in diurnal habitat with a shotgun. When a bird was collected, the age and sex were determined using the technique described by Martin (1964). I then weighed the bird and the esophagus, proventriculus and ventriculus with all their associated material were immediately removed and placed in a jar containing a 10 percent solution of formalin. I examined the carcasses for diseases, deformities, and parasites.

Stomach Examinations

Volumetric Analyses

I determined volumes of stomach contents in the laboratory using the water displacement technique described by Carpenter (1970). This technique involves washing the material out of the organs with a known quantity of water. By subtracting the known volume of wash water from the total volume displaced, the volume of ingested material is obtained. The types and numbers of each food item were recorded if discernible. If not discernible, the material was recorded as "unknown".

Ingestion Stages

I employed a system to describe the digestive stage of the ingested material to supplement information from stomach volumes. If there was material in the esophagus or proventriculus or if the stomach contents were not appreciably altered by the digestive process, the stomach sample was given a value of "1" which signified "early" digestion (Fig. 14).

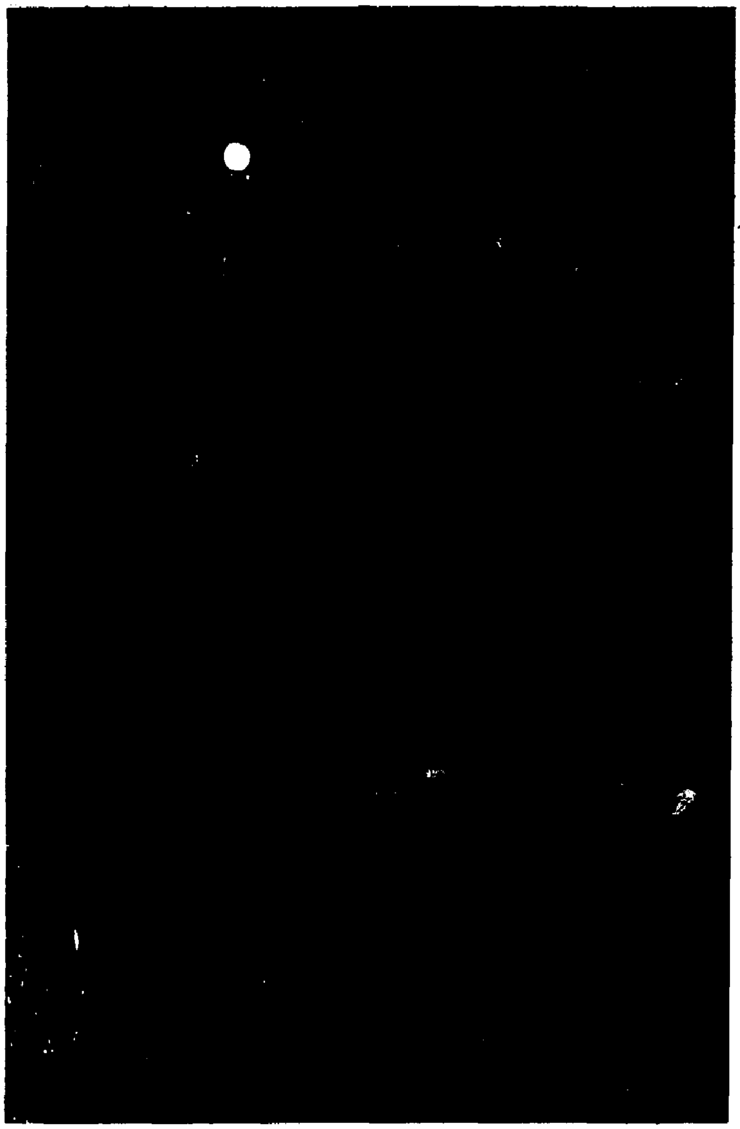


Figure 12. Equipment used for capturing woodcock at night.

Figure 13. Method of collecting woodcock for food habits analyses.

Figure 14. Sample of stomach contents that were designated as an "early" digestion stage.

If digestion was in an "intermediate" stage; that is, the material was affected by digestion but each food item was still intact, the stomach sample was given a value of "2" (Fig. 15). If digestion was "advanced", so that the material was in fragments or significantly altered in structure, the stomach sample was given a value of "3" (Fig. 16).

Comparisons with Flushing Sites

I took soil samples at each flushing point in diurnal cover and the food items in the soil sample were compared to the stomach contents of the woodcock flushed from that point. The soil sample came from a circular plot with a radius of 4.47 inches and excavated to a depth of 3 inches. This area represented 1/100,000 of an acre. The contents were dug with a small garden shovel and placed in a plastic bag. They were analyzed in the laboratory by processing the material through a series of graduated soil sieves. All material, both plant and animal, was identified and recorded. Insect nomenclature was according to Baker (1972) and seed identification was according to Martin and Barkley (1961).

Local Movements Studies

To determine if a relationship existed between the use of nocturnal fields and diurnal habitat, I marked woodcock with reflective back-tags. This marking was done to provide information as to the regularity of use of nocturnal fields as well as shifts in local populations as a result of changes in such environmental variables as weather.

Figure 15. Sample of stomach contents that were designated as an "intermediate" digestion stage.

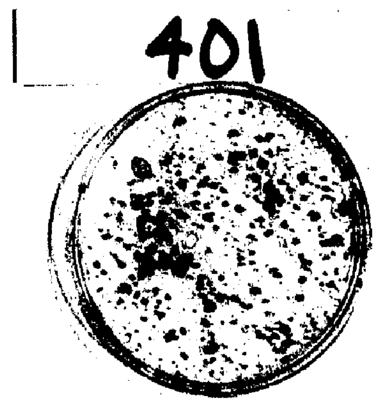


Figure 16. Sample of stomach contents that were designated as an "advanced" digestion stage.

Tagging Methods

I tagged 200 woodcock captured from the nocturnal fields at Grosse Tete with headlights and nets as described by Glasgow (1958). In order to reduce variability induced by age or sex categories, one-fourth of the woodcock tagged were immature males, one-fourth immature females, one-fourth mature males, and one-fourth mature females. If one or more age and sex category was filled and another not, those birds that could not be used were banded with conventional metal leg bands and released. Age and sex of the captured woodcock were determined according to the method described by Martin (1964).

The back-tags were very similar to those described by Britt (1971) except that the Scotchlite tape (3M Co., St. Paul, Minn.) was glued to the surgical latex with epoxy glue because the adhesive on the tape was not capable of withstanding the movements of the bird or the moisture to which it would be exposed. Also, instead of using surgical rubber from 5/8 inch drain tubing, latex rubber from surgical gloves was used because it was more pliable.

Four basic colors were used to mark the birds, one for each age and sex category. Red was used for immature males, white for immature females, blue for adult females, and green for adult males. If spotted in the field during work on other facets of this study, tagged birds were not collected in either diurnal or nocturnal cover. All back-tags were labeled with a reward statement in the hope of increasing returns. The small cost of rewards seemed justifiable if reporting rates were increased.

Other Banding Efforts

During the 3 years of study, 203 additional woodcock were caught on nocturnal-use fields of the three study areas and banded with U. S. Fish and Wildlife Service metal leg bands. This banding was done as a continuance of work conducted in this area for almost 30 years. Records were kept of the number of woodcock seen during these banding efforts so that migration times and localized movements could be identified.

Breeding Activity in Louisiana

Investigations of breeding activity on the wintering grounds were conducted concomitant with habitat studies. Although not an initial objective of this study, prompting by woodcock biologists in northern states led to these investigations as information on breeding activities in Louisiana and other southern states could be beneficial to management decisions. Breeding activity in Louisiana was investigated by two methods. First, biologists, hunters, and other reliable sources were questioned as to their observations of nesting, brood rearing, or of females with eggs collected during the hunting season. Secondly, testicular development in males was used as an indicator of breeding condition. Testes were removed from males that were collected by methods outlined previously for eye and stomach sampling and placed in a 10 percent formalin solution. The collection date and weight of each testis was determined and recorded. Both testes from each specimen were measured and weighed because only very rarely are two avian testes the same size. Samples were obtained from November through February in the winter of 1973-74.

In order to be able to draw inferences about testicular size changes, baseline data about relative testes size were needed. Mr. William B. Krohn, Research Biologist of the United States Fish and Wildlife Service collected woodcock during the breeding seasons of 1970, 1972, and 1973 in Maine. He measured and weighed testes from these birds and made this information available for comparison. Thus, by knowing the approximate maximum size during the peak of the breeding season, testicular development during the late winter months could be evaluated on a comparative basis.

Climatological data for Louisiana were obtained for the period in which the testes samples were collected. This information was then compared to the testes data to see if any correlation between climatic trends and reproductive condition existed.

Random Sample Analyses

In order to draw inferences from habitat information, discerning whether or not the data were representative of woodcock selection or were merely a reflection of the area sampled was important. I therefore collected data at random points in exactly the same manner as for flushing sites. These collections were made on 30 plots at the Morganza study area (Area 1) and 40 plots at the Bayou Choctaw study area (Area 2). The Grosse Tete study area (Area 3) was not sampled. These studies were done during the winter months to avoid seasonal variation in ontogeny of plant species, changes in soil characteristics, or differences in invertebrate communities.

The method of selecting plot locations involved assigning numerical values to compass headings and selecting each value by a random draw.

Distance values were then obtained from a table of random numbers. By this method, each plot was located at a random direction and distance from its predecessor.

RESULTS AND DISCUSSION

Diurnal Habitat

I evaluated habitat variables for woodcock flushes on each of the three study areas. Random samples of habitat variables were made for two of the three study areas. The results of the flushing point analysis for each area were then compared with one another as well as with the results of the random samples.

Soil Characteristics

Soils are an important part of the habitat of any animal species because they play a major role in determining the composition of plant communities. However, with a ground-dwelling species such as the woodcock, soils are particularly important because they dictate, to a substantial extent, the amount and types of food as well as their availability. Liscinsky (1972) has noted that beneath or near a woodcock covert a soil must be present that can support a constant supply of woodcock foods. Soil moisture, soil pH and litter depth were considered to be important indicants of soil conditions that might influence woodcock habitat preferences and so were chosen for measurement. Means, variances, and coefficients of variation were computed for these factors and t-distributions were used to test for differences. The results of these tests are presented in Tables 1, 2, and 3.

Table 1. Results of t-tests comparing soil pH between random plots on two study areas, flushing points on three study areas, and between random plots and flushing points on two study areas.**

Random Plots

Morganza (Area 1)	Bayou Choctaw (Area 2)	Total
$\bar{x}$ = 7.9	$\bar{x}$ = 6.8	$\bar{x}$ = 7.2
σ = 1.8	σ = 1.6	σ = 2.3
c.v. = 25.6	c.v. = 19.4	c.v. = 11.6

t-test for Area 1 compared to Area 2
d.f. = 68 t cal. = 2.69 t tab. = 1.99*

Flushing Points

Morganza (Area 1)	Bayou Choctaw (Area 2)	Grosse Tete (Area 3)	Total
$\bar{x}$ = 7.8	$\bar{x}$ = 6.7	$\bar{x}$ = 7.1	$\bar{x}$ = 6.9
σ = 1.6	σ = 1.9	σ = 1.4	σ = 2.2
c.v. = 21.4	c.v. = 20.1	c.v. = 12.4	c.v. = 8.6

t-test for Area 1 compared to Area 2		
d.f. = 147	t cal. = 3.35	t tab. = 1.96*
t-test for Area 1 compared to Area 3		
d.f. = 152	t cal. = 2.31	t tab. = 1.96*
t-test for Area 2 compared to Area 3		
d.f. = 99	t cal. = 1.21	t tab. = 1.98*

Random Plots Compared to Flushing Points

t-test for random plots compared to flushing points on Area 1		
d.f. = 129	t cal. = .58	t tab. = 1.96
t-test for random plots compared to flushing points on Area 2		
d.f. = 86	t cal. = .26	t tab. = 1.99
t-test for total random plots compared to total flushing points		
d.f. = 270	t cal. = .97	t tab. = 1.96

*Indicates significant difference at $p < .05$ confidence level.

**All tabular values are from Snedecor and Cochran (1967) unless stated otherwise

Table 2. Results of t-tests comparing soil moisture between random plots on two study areas, flushing points on three study areas, and between random plots and flushing points on two study areas.

Random Plots

Morganza (Area 1)	Bayou Choctaw (Area 2)	Total
$\bar{x}$ = 59.50	$\bar{x}$ = 57.20	$\bar{x}$ = 58.18
σ = 6.74	σ = 6.07	σ = 6.42
c.v. = 11.33	c.v. = 10.62	c.v. = 11.04

t-test for Area 1 compared to Area 2

d.f. = 68	t cal. = 1.49	t tab. = 1.99

Flushing Points

Morganza (Area 1)	Bayou Choctaw (Area 2)	Grosse Tete (Area 3)	Total
$\bar{x}$ = 84.15	$\bar{x}$ = 85.92	$\bar{x}$ = 84.51	$\bar{x}$ = 84.66
σ = 6.86	σ = 6.19	σ = 7.54	σ = 6.89
c.v. = 8.15	c.v. = 7.20	c.v. = 8.92	c.v. = 8.15

t-test for Area 1 compared to Area 2		
d.f. = 147	t cal. = 1.52	t tab. = 1.96
t-test for Area 1 compared to Area 3		
d.f. = 152	t cal. = .29	t tab. = 1.96
t-test for Area 2 compared to Area 3		
d.f. = 99	t cal. = 1.02	t tab. = 1.98

Random Plots Compared to Flushing Points

t-test for random plots compared to flushing points on Area 1		
d.f. = 129	t cal. = 17.34	t tab. = 1.96*
t-test for random plots compared to flushing points on Area 2		
d.f. = 86	t cal. = 21.86	t tab. = 1.96*
t-test for total random plots compared to total flushing points		
d.f. = 270	t cal. = 28.16	t tab. = 1.96*

*Indicates significant difference at $p < .05$ confidence level.

Table 3. Results of t-tests comparing litter depth between random plots on two study areas, flushing points on three study areas, and between random plots and flushing points on two study areas.

Random Plots

Morganza (Area 1)	Bayou Choctaw (Area 2)	Total
$\bar{x}$ = 1.75	$\bar{x}$ = 1.82	$\bar{x}$ = 1.79
σ = .54	σ = .79	σ = .69
c.v. = 30.71	c.v. = 43.23	c.v. = 38.42

t-test for Area 1 compared to Area 2
d.f. = 68 t cal. = .448 t tab. = 1.99

Flushing Points

Morganza (Area 1)	Bayou Choctaw (Area 2)	Grosse Tete (Area 3)	Total
$\bar{x}$ = 1.54	$\bar{x}$ = 1.68	$\bar{x}$ = 1.52	$\bar{x}$ = 1.57
σ = .39	σ = .32	σ = .39	σ = .38
c.v. = 25.10	c.v. = 19.26	c.v. = 25.60	c.v. = 24.02

t-test for Area 1 compared to Area 2
d.f. = 147 t cal. = 2.17 t tab. = 1.96*
t-test for Area 1 compared to Area 3
d.f. = 152 t cal. = .30 t tab. = 1.96
t-test for Area 2 compared to Area 3
d.f. = 99 t cal. = 2.24 t tab. = 1.98*

Random Plots Compared to Flushing Points

t-test for random plots compared to flushing points on Area 1
d.f. = 129 t cal. = 2.32 t tab. = 1.96*
t-test for random plots compared to flushing points on Area 2
d.f. = 86 t cal. = 1.19 t tab. = 1.99
t-test for total random plots compared to total flushing points
d.f. = 270 t cal. = 3.39 t tab. = 1.96*

*Indicated significant difference at p<.05 confidence level.

Soil pH

The study area at Morganza (Area 1) had significantly higher soil pH than did the study area of Bayou Choctaw (Area 2) (see Table 1). Area 1 is an area of more recently deposited soils, particularly sand, and the mean pH of 7.9 reflects a more basic nature than the soils from Area 2, which had a mean pH of 6.8. Area 2 is an area of older soils with a high clay content and no sand.

The significant differences of soil pH between Areas 1 and 2 were also encountered in the flushing point analysis. However, the flushing points on Grosse Tete (Area 3) were not significantly different from those on Area 2. This similarity would be expected because both of these areas have about the same soil composition.

Neither of the comparisons of random plots and flushing points between Areas 1 and 2 showed any differences in soil pH. The comparison of mean pH of the total combined random plots and the total combined flushing points also showed no significant difference. A wide range of values of soil pH on each area, as evidenced by the high variance around each mean, was observed. However, because the comparison showed no difference between flushing points and random plots, woodcock either do not choose areas of one specific soil pH, or any preference they might have was not detectable with this method of analysis. This information also indicates that soil pH is not a limiting factor in producing the preferred vegetation and food items required by woodcock in their diurnal habitat.

Although no previous work has been done on the specific effects of soil pH for determining vegetative forms favorable to woodcock habitat, several workers have explored the effects of soil pH on the distribution of woodcock foods, primarily earthworms. Most workers feel that soil pH is not a limiting factor on the distribution of earthworms unless it is extremely high or low. Miller (1957) found earthworms in Pennsylvania to be most abundant in soils with a pH between 4.6 and 6.0, Mendall and Aldous (1943) found more earthworms in soils with a pH between 5.00 and 5.75, and Olson (1928) found most earthworms in Ohio in soils with a pH ranging from 4.5 to 8.7. Some workers have reported larger numbers of earthworms in soils with a high pH. Murchie (1954) found in Michigan that soils with a pH greater than 6.0 support more earthworms than soils with a lower pH. Ensminger (1954) working in south-central Louisiana reported similar results and observed that soils with a pH lower than 6.0 supported fewer worms than did soils with a pH greater than 6.0.

In light of these works, and the pH range that I found, soil pH was probably not limiting to the occurrence of earthworms on any of the three study areas.

Soil Moisture

Soil moisture is possibly one of the most important soil characteristics in terms of woodcock habitat. However, whether or not certain soil moisture levels are solely responsible for making an area attractive to woodcock or if certain levels of soil moisture merely dictate the vegetation or feeding conditions favorable to woodcock is a matter of conjecture.

A comparison of the random plots between Morganza (Area 1) and Bayou Choctaw (Area 2) showed the means to be quite similar (see Table 2). The t-test showed no significant difference between Area 1 and Area 2. Likewise, the comparisons of the flushing points between all three areas showed the means to be similar and none of the t-tests showed any significant differences. However, when the random plots were compared to the flushing points, the t-tests all showed significant differences. The differences between the means of the random plots and the flushing points indicates that flushes occurred in areas that had soil moisture values approximately 30 percent higher than the random or "typical" sites.

Although woodcock showed an apparent preference for areas of higher soil moisture, this preference was not necessarily for higher soil moisture _per se_. There may be a preference for some factor associated with higher soil moisture. Several workers have noted a preference by woodcock for cover provided by moist sites during the summer months. Pettingill (1936) mentioned the importance of moist areas, particularly during the summer months. Mendall and Aldous (1943), Sheldon (1967), and Blankenship (1957) have noted that the majority of diurnal habitats occupied during the summer months are in areas of high soil moisture. Liscinsky (1964) identified summer habitat in Pennsylvania as being composed primarily of bottomland plants which typically grow on wet sites. The applicability of these observations to habitat on the wintering ground may be questionable because during the summer there are periods of low moisture that may make soil moisture more of a limiting factor than it is in Louisiana during the winter months. However, these observations serve to illustrate the fact that woodcock may select certain habitats on the basis of soil moisture characteristics.

Several workers in Louisiana have commented on the importance of soil moisture to woodcock habitat. Reid and Goodrum (1955), working in north-central Louisiana, noted that in dry winters the soils in the post oak (_Quercus stellata_) flats and blackjack oak (_Q. marilandica_) hillsides become hard-packed and woodcock use these areas very little. However, during winters of heavy rainfall, they observed these areas to be used heavily. Glasgow (1956) observed that there were more woodcock in the bottomland hardwood areas of south-central Louisiana when there was an early winter cold front and relatively high soil moisture. He reported, "I received many reports of a scarcity of woodcock in pine sections of Southwest Louisiana last winter (1951-1952). At the time these reports were being received, we had heavy concentrations of woodcock in the surrounding parishes. These concentrations were higher than I have observed in other years. I am convinced that woodcock must vacate large sections of the state when dry conditions prevail and move to areas where moist conditions exist." Britt (1971) noted changes in habitat preference as a result of rain. During periods of drought, woodcock abandoned many "ideal" coverts in preference to areas around creeks, ponds, or other wet areas.

Exactly what factors or interaction of factors that make soil moisture important to woodcock habitat is not clear. However, most workers feel the main effect of soil moisture on woodcock habitat to be its influence on the occurrence of earthworms. Workers in Massachusetts have found good earthworm populations in damp soils where drainage water came near the ground surface and caused better soil aeration (Sheldon 1967 p. 81, personal communication with Stebbings, 1961). Miller (1957) found that extremely high or low soil drainages were detrimental to earthworm populations. Murchie (1954) found that upland soils were no longer suitable for earthworms once the water holding capacity was greater than 100 percent or less than 45 percent. Evans and McGuild (1948) assumed the upper and lower soil moisture tolerance limits were

42 and 28 percent respectively and Olson (1928) believed these to be about 35 and 12 percent, respectively. Ensminger (1954) found that in nocturnal usage fields of south-central Louisiana more earthworms were found in soil samples with moisture contents of about 34 percent than in samples with moisture contents of 20 percent. He found very few worms in areas of standing water or areas with soil moisture approaching 85 percent. Harman (1952) and McGuild (1951) have found that earthworms draw themselves deeper into the ground when soil conditions are not optimum and if flooded, they will vacate an area.

In light of this information, the soil moisture means for the random plots on Areas 1 and 2 (59.9% and 57.2%, respectively) are probably approaching the upper soil moisture limits of preference by earthworms and the mean percentages for the flushing points on Areas 1, 2, and 3 (85.15%, 85.92%, and 84.51%, respectively) are too high to provide ideal conditions for earthworms. Considering the results of the t-tests between random plots and flushing points, woodcock were found on sites too moist for earthworms. This observation was substantiated by the fact that very few earthworms were recovered from soil samples taken from flushing sites. These soil samples were taken in conjunction with the food habits portion of this study and the results are presented in a later section.

If food attracted woodcock to these moist areas, then material other than earthworms must have been the primary food item. The possibilities that cover preferences were responsible for the presence of woodcock in these moist areas are explored more thoroughly in another part of this paper.

Litter depth

I found the random plots on Morganza (Area 1) to have approximately the same litter depth as the random plots on Bayou Choctaw (Area 2) (see Table 3). The flushing point analysis showed that flushes from Areas 1 and 3 (Grosse Tete) occurred from points with comparable litter depth, however; Area 2 had significantly more litter at the flushing points. When the random plots were compared to the flushing points, Area 2 showed no significant differences.

These data suggest that most woodcock preferred diurnal cover that contained less litter than encountered on the "typical" site. This was not the case for Area 2, however differences of vegetation from which most woodcock were flushed on Area 2 as compared with Areas 1 and 3 were probably responsible for these different litter measurements. The majority of flushes on Area 2 came from dewberry or blackberry thickets of medium or light density. These thickets frequently had rather deep layers of litter for two reasons. First, they were under stands of hardwoods that contributed substantial leaf litter. Secondly, high waters often carried litter to these sites, which were typically on the side of ridges and when these waters receded the litter remained. These conditions were not found on either of the other two areas. While admittedly speculative in nature, this hypothesis is more logical than assuming woodcock had different preferences of litter depth on Area 2 than on the other areas. Also, the probability of sampling or calculating error is relatively remote considering the closeness of all coefficients of variation.

The literature offers little to indicate that litter depth may be of a controlling nature in habitat selection by woodcock. Litter depth governs, to some extent, the amount of organic matter in the soil. Several workers have found that organic material may influence the distribution of certain woodcock foods. Olson (1928) determined that soils with very high or low quantities of organic matter are unfavorable to earthworms. Marshall (1958) analyzed the soil types of 47 singing grounds in Minnesota and found that they were composed of loamy or alluvial soils, which are high in organic material. However, Blankenship (1957) noted that a majority of singing grounds in Michigan were on sandy soils, which are low in organic material. Miller (1957) concluded that organic matter had less effect on the abundance of earthworms than any other soil characteristic. He also noted that litter was important to woodcock in terms of providing plant foods. He found that plant debris made up the majority of the food material collected from woodcock stomachs in the fall of 1955 and 1956 in Pennsylvania. The majority of the plant debris that he found in stomachs was material from plant species that commonly occur in forest litter.

Sheldon (1967) noted that tree litter may serve to make certain areas more attractive to woodcock. He postulated that litter may be the reason certain tree species such as alder are associated with good woodcock habitat. In this regard, Handley (1954), working in England, found that litter under alder trees had a much higher percent of nitrogen than did litter under any of 24 other tree species he tested. This higher nitrogen level may be responsible for larger numbers of woodcock foods or for the occurrence of certain herbaceous plants, which may be attractive to woodcock.

Although Area 2 showed no significant difference between litter depth on random plots and on flushing points, the remaining test data showed that woodcock were flushed from areas with significantly less litter than was found on random plots. Although the implications of these findings in terms of previous works are inconclusive, several inferences can be drawn. First, the apparent selection of areas with less litter may be a reflection of Sheldon's (1967) observation that woodcock like to have flat, unobstructed areas so they can walk about or move around freely. Large piles of litter would not permit this movement. Secondly, deep litter may impair probing for subterranean food items and therefore, woodcock selected areas with less litter. However, because the soil moisture values at the flushing sites indicated an unsuitable environment for earthworms, probing may have been minimal or may have been directed toward a food item other than earthworms. Considering Miller's findings on the amount of plant material ingested, the areas of less litter may have made feeding on plant material easier. Location of small items such as plant seeds or invertebrates would be easier in areas of less litter. This consideration will be discussed more in the section on feeding habits. Finally, the areas of less litter may be indicative of sites capable of supporting species of vegetation that make good woodcock habitat. Sheldon's observations on the possible correlation between litter and alder thickets for woodcock habitat in the northeast may have a sequel for certain cover types on the wintering ground.

Vegetation Analysis

I divided the vegetation analysis into three portions and sampled 202 flushing points on three study areas. These analyses included a mil-acre sample consisting of the frequency and coverage of the vegetation at each flushing site and a 1/100 acre sample consisting of the frequency, size, and density of all overhead species. An overhead species was considered to be any tree species that was 9 inches dbh or larger. To give an indication of the normal or typical site on each area, I took 70 random samples on two of the three study areas and the sampling procedures were exactly the same as those used on the flushing sites.

Vegetation Frequency and Coverage

Thirty-two plant groups were found to occur commonly on the flushing sites on the three study areas and 15 other types occurred less prevalently. Table 22 (Appendix), presents a listing of all plants sampled on all three study areas. Plants such as grasses were placed only in family groups while others, such as oaks, were placed in generic groupings. This grouping was necessitated by difficulties encountered with identifying young, understory specimens to species during the winter months. Table 4 shows the prevalent plants found on the random plots while Table 5 shows the same information for the flushing points. The number of plots in which a plant occurred is listed in the first column while the percent of the sampled plots in which each species occurred is presented in the second column. The relative ranking of each species is given in the third column. Table 6 presents data acquired on the percent coverage of vegetation on Morganza (Area 1) and Bayou Choctaw (Area 2). Coverage, as expressed in this table, is the coverage per plot in terms of quarters of each plot occupied by a plant species. This table provides a comparison of random plots and flushing points along with the relative ranking of each plant species for both

Table 4. Vegetation sampled on 70 random milacre plots from two study areas.

Species of Vegetation	Area 1 (30 plots) number of plots in which found	Area 1 % of total plots	Area 1 ranking by frequency of occurrence	Area 2 (40 plots) number of plots in which found	Area 2 % of total plots	Area 2 ranking by frequency of occurrence	Total (70 plots) number of plots in which found	Total % of total plots	Total ranking by frequency of occurrence
Quercus sp.	22	73	2	16	40	5	38	54	4
Rúbus sp.	10	33	4	22	55	3	32	46	6
Arundinaria gigantea	10	33	4				10	14	11
Berchemia scandens	5	16	6	13	32	7	18	26	7
Poaceae	24	80	1	28	70	2	52	74	1
Smilax sp.	22	73	2	18	45	4	40	57	2
Planera aquatica				6	15	10	6	8	14
Senecio glabellus				9	22	9	9	13	12
Sambucus canadensis				15	38	6	15	21	9
Anisostichus capreolata	3	10	7	1	2	15	4	6	17
Liquidambar stryaciflua	16	53	3	8	45	4	34	48	5
Celtis laevigata	3	10	7	2	5	14	5	7	15
Crataegus sp.				2	5	14	2	3	18
Aster spp.				1	2	15	1	1	19
Gleditsia triacanthos									
Frasinus sp.	1	3	9				1	1	19
Lonicera				4	10	12	4	6	17

XUM

Table 4. (continued)

Species of Vegetation	Area 1 (30 plots)			Area 2 (40 plots)			Total (70 plots)		
	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence
Lindera benzoin									
Rhus radicans	10	33	4	29	72	1	39	56	3
Cornus sp.	7	23	5	10	25	8	17	24	8
Acer negundo	3	10	7	1	2	15	4	6	17
Solidago sp.									
Forbs*	7	23	5	3	8	13	10	14	10
Nyssa sp.									
Polystichum acrostichoides									
Carya sp.	2	7	8				2	3	18
Vicia spp.				1	2	15	1	1	19
Acer rubrum var. drummondii	3	10	7	4	10	12	7	10	13
Polygonum sp.									
Viola affinis	1	3	9	10	25	8	11	16	10
Ilex decidua				5	12	11	5	7	16
Sabal minor									

*Forbs are used to describe any nonwoody plant whose aerial portion is relatively short lived. This term excludes the grasses.

Table 5. Vegetation sampled on 202 flushing points from 3 study areas.

Species of Vegetation	Area 1 (101 plots)			Area 2 (48 plots)			Area 3 (53 plots)			Total (202 plots)		
	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence
Quercus sp.	62	61	1	26	54	3	34	64	3	122	60	3
Rubus sp.	62	61	1	45	94	1	47	89	1	154	76	1
Arundinaria gigantea	56	55	3				2	4	14	58	29	8
Berchemia scandens	52	51	4	25	52	4	29	55	4	106	52	4
Poaceae	60	59	2	33	69	2	42	79	2	135	67	2
Smilax sp.	45	44	6	21	44	5	28	53	5	94	46	5
Planera aquatica							4	8	13	4	2	
Senecio glabellus	1	1	20				7	13	11	8	4	16
Sambucus canadensis	18	18	11	16	33	8	8	15	10	42	21	11
Anisostichus capreolata	46	46	5	17	35	7	11	21	9	74	37	6
Liquidambar styraciflua	19	19	10	5	10	11	2	4	14	26	13	13
Celtis laevigata	28	28	8	18	38	6	16	30	6	62	31	7
Crataegus sp.	7	7	14	1	2	14	2	4	14	10	5	15
Aster spp.	5	5	16	1	2	14	2	4	14	8	4	16
Gleditsia triacanthos	4	4	17	1	2	14				5	2	17
Fraxinus sp.	2	2	19				2	4	14	4	2	17
Lonicera japonica	14	14	12	15	31	9	12	23	8	41	20	12
Lindera benzoin	3	3	18	2	4	13				5	2	17

Table 5. (continued)

Species of Vegetation	Area 1 (101 plots)			Area 2 (48 plots)			Area 3 (53 plots)			Total (202 plots)		
	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence	number of plots in which found	% of total plots	ranking by frequency of occurrence
Rhus radicans	4	4	17	4	8	12	1	2	15	9	4	16
Cornus sp.	6	6	15	4	8	12	5	9	12	15	7	14
Acer negundo	25	25	9	12	25	10	14	26	7	51	25	10
Solidago sp.	2	2	19				2	4	14	4	2	17
Forbs*	8	8	13				2	4	14	10	5	15
Nyssa sp.	3	3	18				2	4	14	5	2	17
Polystichum acrostichoides	3	3	18				1	2	15	4	2	17
Carya sp.	2	2	19				1	2	15	3	1	18
Vicia spp.	3	3	18				2	4	14	3	1	18
Acer rubrum var. drummondii	30	30	7	15	31	9	12	23	18	57	28	9
Polygonum sp.							2	4	14	2	1	18
Viola affinis	4	4	17	2	4	13	2	4	14	8	4	16
Ilex decidua	1	1	20							1	1	18
Sabal minor	1	1	20							1	1	18

* Forbs are used to describe any nonwoody plant whose aerial portion is relatively short lived. This term excludes the grasses.

Table 6. Mean percent coverage per plot and relative ranking of coverage of plant species on two study areas (both random plots and flushing points) and results of t-tests showing significant differences of coverage between plants on random plots versus flushing points.

	Mean coverage per plot and ranking on Area 1				Mean coverage per plot and ranking on Area 2				Mean coverage per plot and total ranking			
Plant Species	Random plots		Flushing points		Random plots		Flushing points		Random plots		Flushing points	
Quercus sp.	50.0%	2	53.6%	10	45.3%	11	61.5%	6	48.0%	8	55.7%	8
Rubus sp.	42.5	4	56.4	6	73.9	4	86.1	2*	64.1	3	72.6	4
Arundinaria gigantea	30.0	11	95.1	2*					30.0	17	92.7	2*
Berchemia scandens	35.0	7	62.0	5*	55.8	9	63.0	4	50.0	7	63.4	6*
Poaceae	65.6	1	69.6	4	74.1	3	68.9	3	70.2	2	66.7	5
Smilax sp.	37.5	6	55.0	9*	48.6	10	58.3	7	42.5	10	53.4	9*
Planera aquatica					37.5	14			37.5	12	25.0	20
Senecio glabellus			25.0	18	44.4	12			44.4	9	37.5	16
Sambucus canadensis			34.7	15	60.0	6	48.4	9	60.0	4	42.3	14*
Anisostichus capreolata	33.3	8	55.4	8	25.0	16	42.6	10	31.2	16	53.4	9
Liquidambar styraciflua	32.8	9	31.6	17	25.0	16	35.0	12	32.3	15	33.6	20
Celtis laevigata	37.5	6	37.5	14	25.0	16	33.3	13	33.6	14	35.6	18
Crataegus sp.			25.0	18	37.5	14	25.0	14	37.5	12	25.0	22*
Aster spp.			45.0	12	25.0	16	25.0	14	25.0	18	50.0	19
Gleditsia triacanthos			25.0	18			25.0	14			25.0	22
Fraxinus sp.	25.0	13	25.0	18					25.0	18	25.0	22

Table 6. (continued)

Plant Species	Mean coverage per plot and ranking on Area 1				Mean coverage per plot and ranking on Area 2				Mean coverage per plot and total ranking			
	Random plots		Flushing points		Random plots		Flushing points		Random plots		Flushing points	
Lonicera japonica			80.4%	3	81.2%	1	86.7%	1	81.2%	1	83.5%	3
Lindera benzoin			25.0	18			62.5	5			40.0	15
Rhus radicans	32.5%	10	25.0	18	64.6	5	50.0	8	56.4	5	36.1	17
Cornus sp.	42.9	3	25.0	18	25.0	16	37.5	11*	32.3	15	30.0	21
Acer negundo	41.6	5	55.0	9	40.3	13	33.3	13	40.5	11	44.0	13
Solidago sp.			100.0	1							100.0	1
Forbs**	28.6	12	50.0	11	75.0	3			42.5	10	60.0	7
Nyssa sp.			33.3	16							30.0	21
Polystichum acrosti- choides			41.7	13							37.5	16
Carya sp.	25.5	13	25.0	18					25.0	18	25.0	22
Vicia spp.			25.0	18	25.0	16			25.0	18	25.0	22
Acer rubrum var. drum - mondii	28.6	12	25.0	18	56.2	8	62.5	5	34.7	13	42.3	14
Polygonum sp.											25.0	22
Viola affinis	25.0	13	56.2	7	57.5	7	37.5	11	54.5	6	46.9	12
Ilex decidua			25.0	18	30.0	15			30.0	17	25.0	22
Sabal minor	25.0	18									25.0	22

*Indicates difference at P .05 level of significance.

**Forbs are used to describe any non-woody plant whose aerial portion is relatively short lived. This term excludes the grasses.

sampling techniques. Also indicated are differences between plant coverages that were shown to be statistically different using a t-test.

In the following discussion, only 13 of the 47 recorded plant species are considered because this was the number of plants that had a high enough frequency value to allow meaningful comparisons within and between areas.

Plants used for analyses

The 13 plant types, which occurred frequently enough to allow analysis, included five genera of trees, five species of vines, one shrub, and two categories of grasses. These plants were important to the determination of prime diurnal cover for woodcock either by actually providing cover or as indicators of characteristics that made a site attractive to woodcock. Site requirements and changes in distributions of these plants will be discussed in this section, but generalities regarding site requirements for some of the types of lesser vegetation are somewhat meaningless. As Sharp (1974) states: "It is pointless to try to lay down hard and fast rules on the soil and moisture requirements of shrubs and vines in general." The emphasis, therefore, will be on changes in distribution between areas or between random plots and flushing points and the implications of these changes to habitat preferences.

1. Blackberry or dewberry (Rubus spp.): -- Blackberries and dewberries form dense thickets that may be several acres in size and 7 to 8 feet tall. Generally speaking, blackberries have erect stems while dewberries have trailing stems, although the site requirements are about the same for both groups. To grow prolifically, Rubus spp. must have ample sunlight and a well-drained soil with not too much moisture

(Core 1974, Maisenhelder 1958). Although these plants grow in dense thickets, the penetration of light is often sufficient to allow hardwood seedlings to grow under the thickets. Also, litter often falls through the thickets to the ground, is held in place by the vines, and therefore acts as mulch for hardwood seedlings (Maisenhelder 1958, Moore 1961).

The analysis showed higher frequencies and coverages of Rubus spp. on the flushing points as compared to the sample plots (see Tables 4 and 5). The frequency for Rubus spp. on the random plots was not as high for Area 1 as for Area 2. Although both areas showed an increase in frequency for the flushing points as compared to the random plots, Area 2 showed a much larger increase than did Area 1. Woodcock used sites occupied by Rubus spp. more on Area 2 than on Area 1 probably because of differences in plant communities between the two areas. This subject will be developed more fully later in this section.

The analysis of coverage for Rubus spp. showed a significant increase on the flushing points as compared to the random plots on Area 2 and showed slight increases on the flushing points on Area 1 and for the totals of all areas. These higher coverage values for Rubus spp. on flushing points as compared with random plots indicates a need for dense cover in the diurnal habitat for woodcock (see Table 6).

When the frequency and coverage data are combined, indications are that woodcock select areas of dense coverage by Rubus spp., or conditions suitable for these dense coverages whenever this species occurs in diurnal habitat. Also, sites within thickets which contain denser concentrations of this genera are utilized more frequently.

2. Switch-cane (Arundinaria gigantea): -- Switch-cane, like Rubus spp. grows in dense thickets that are frequently almost impenetrable. However, these thickets or canebrakes are generally much denser than are Rubus spp. thickets. When switch-cane reaches 7 to 8 feet tall, it usually creates enough shade to suppress hardwood reproduction (Putnam et al. 1960). Switch-cane grows on light soils such as sandy loam or silty loam and it uses a moist, well-drained site (Maisenhelder 1958). The soils on Area 1 contained more sand than those of Area 2 or Area 3. This probably accounts for the absence of switch-cane on Area 2 and the low frequencies on Area 3.

Switch-cane was an important component of woodcock habitat on Area 1. This species was found on 33 percent of the random plots and 55 percent of the flushing points, indicating that woodcock choose this plant as a component of their diurnal cover in proportions higher than its natural occurrence (see Tables 4 and 5).

Also indicative of the importance of this plant to diurnal woodcock cover is the coverage analysis presented in Table 6. The average cover on the random plots on Area 1 was 30 percent while the average coverage for flushing points was 95 percent. This difference between coverage values was statistically significant and indicates, as did the data for Rubus spp., that woodcock prefer densely vegetated areas.

3. Rattan-vine (Berchemia scandens): -- Rattan-vine is common to most bottomland sites and was common to all three areas used in this study (see Table 6). However, it was much more frequently encountered on plots from which woodcock were flushed than on the random plots. Also, the coverages by this species on the random plots were significantly lower for Morganza (Area 1) and for the total plots than the

flushing point coverages. Bayou Choctaw (Area 2) however, did not show a significant difference between the two sampling procedures although the flushing point coverage values were higher. These data indicate that the sites containing rattan-vine were favored more by woodcock when the percents of coverage were higher than the average coverage value typically displayed by this species.

The frequency and coverage data suggest that woodcock favor sites containing rattan-vine for their diurnal cover and of those sites, the ones with denser growths of this species are preferred. Rather than being attractive to woodcock itself, this rattan-vine cover is probably more an indicator of site characteristics favorable to woodcock habitat. Rattan requires trees or other objects for support; ideally, this support is in the form of horizontally oriented structures such as low limbs parallel to the ground or blown down trees (Putnam et al. 1960). The leaves, flowers, and fruit are often high in trees so that they may photosynthesize, while the main stems of the vines live in the understory and are able to tolerate extreme amounts of shading. Also, rattan-vine prefers moist to wet sites (Maisenhelder 1958). Because the vegetation measured at each woodcock flushing site was 6 feet or less from the ground surface, almost all of the rattan-vine sampled was the stem portion, which was usually in shaded areas and deriving its support from blown down trees or other similar structures. Also, the ability to thrive on wet sites enabled this species to persist on flushing sites that had the high soil moisture values alluded to previously in this paper.

The high frequency and coverage values observed for this species on the flushing sites are thus indicative of shaded, moist sites characterized by blowdowns, or other similar structures in the forest understory.

4. Greenbrier (*Smilax* spp.): -- Greenbrier is another common plant of bottomland hardwood areas and several species were found on the three study areas. Common greenbrier (*S. rotundifolia*) and saw greenbrier (*S. bona-nox*) were probably the two most commonly found species on the three study areas, however as Sharp (1974) has observed, the growth pattern for almost all greenbriers is the same; therefore, for narrative purposes, they will be discussed simultaneously.

This genus was encountered more frequently on the random plots than on the flushing points at Morganza (Area 1) (see Tables 4 and 5). On Bayou Choctaw (Area 2) the frequencies were about the same. When Grosse Tete (Area 3) was added to the total flushing point analysis, the total flushing points contained less greenbrier than did the total random plots. The coverage values however, indicate that greenbrier was significantly denser on the flushing points than on the random plots on Area 1 and slightly greater on Area 2 and for the total plot analysis (see Table 6). Although greenbrier occurred on fewer flushing points than random plots, the coverage values on the flushing points were higher than those on the random plots.

This information provides further insight into cover selection by woodcock. Greenbrier is a vine that climbs by tendrils and if shaded, moves toward light. Greenbrier requires sunlight to grow best and the primary cultural practice is to free this species from shading. Also, all greenbriers grow from either underground stems or tubers. Neither of these structures can tolerate excessive soil moisture and greenbriers therefore grow best on well-drained soils (Smith 1974).

The conclusions that can be drawn about woodcock habitat from an analysis of the distribution of greenbrier are two-fold. First, woodcock do not prefer areas of a light intensity high enough to permit common and widespread growths of greenbrier and secondly, the lower soil moisture necessary for greenbrier is unfavorable for sites chosen by woodcock as diurnal habitat. The higher coverage values of greenbrier on the flushing points as compared to the random plots indicate that if woodcock are found in association with greenbrier, the coverage values must be higher than those found on random or "typical" sites.

5. Japanese honeysuckle (Lonicera japonica): -- Japanese honeysuckle, although a common bottomland plant, was not found in large quantities on any of the three study areas. Because this species requires sandy loam soils to make optimal growth (Brunett 1967), and because it is usually found on higher flats away from excessive soil moisture (Maisenhelder 1958), the three study areas were probably not sandy enough and had soil moistures too high to provide optimum conditions for this species.

The frequencies of occurrence were higher for the flushing points on both study areas (see Tables 4 and 5). It would therefore appear that there was a selection by woodcock for sites containing Japanese honeysuckle. The closeness of the coverage values on the random plots and the flushing points, however, suggests that there was no selection by woodcock for any particular amount of coverage. Because the coverage values were so high on both random plots and flushing points, there is reason to believe that this species usually grows in high densities. Putnam et al. (1960) have observed that Japanese honeysuckle's growth form is a low, dense mat that climbs saplings or any other object in the forest. Hall and Goodrum (1961) have reported layering in Japanese honeysuckle mats and have noted that if uncontrolled, it will strangle and overwhelm low-growing plants and trees. Jackson (1974) reports: "The plant's growth form effectively reduces sunlight and moisture available to other plants, and only the most competitive species can survive in association with Japanese honeysuckle."

Because this species is rarely found in low densities, the higher frequencies observed for the flushing points as compared to the random plots are an indication that woodcock prefer this species as diurnal cover. Perhaps if a study area had been chosen with prolific growths of this species, more definitive information could be derived as to its worth for woodcock habitat.

6. Poison ivy (Rhus radicans): -- Poison ivy was common to all three study areas, particularly Bayou Choctaw (Area 2). This species occurred on 56 percent of the total random plots making it one of the most frequently occurring plants studied. However, frequencies for this species on the flushing points were substantially lower than those found on the random plots (4 percent of the total flushing points analyzed) (see Tables 4 and 5). The coverage values, however exhibited very little difference between the random plots and the flushing points on each area (see Table 6). The coverage values for the random plots and the flushing points on Area 2 were each almost twice as large as those values reported for Morganza (Area 1). In other words, flushes occurred

from sites containing amounts of this species that were representative of its abundance on the study areas. Woodcock apparently do not select any particular density of this species.

The substantially lower frequency on the flushing points suggests that woodcock select against sites on which poison ivy grows for their diurnal cover. The data presented for amounts of coverage indicate that flushing sites are no different than random plots with regard to the distribution of this species.

This apparent selection against sites on which this species grows is probably due to its growth habits and requirements. Poison ivy prefers moist, well-drained sites, but not excessively wet ones (Putnam et al. 1960). It requires substantial amounts of light to grow well and is therefore usually found in thickets, open woods or in fence rows. When in shaded areas, it climbs by aerial roots into crowns of trees so that its leaves can carry out photosynthesis (Maisenhelder 1958).

Because the frequency data indicated that woodcock select against sites on which poison ivy grows and because optimum poison ivy sites are characterized by openings and well-drained sites, woodcock habitat must consist of something other than these characteristics. Indications are that woodcock prefer areas of higher soil moisture and lower light intensities than found on sites containing poison ivy.

7. Cross-vine (Anisostichus capreolata): -- This species was found in abundance on all three study areas, although it was associated much more frequently with the flushing points than with the random plots (see Tables 4 and 5). Also, the coverage values for the flushing points

were higher than for the random plots (see Table 6). Woodcock apparently prefer sites with which cross-vine is associated for their diurnal cover.

Rather than provide any kind of diurnal habitat, this species is probably more of an indicator of a preferred type of site. It is a woody vine with a thick fleshy taproot that climbs by tendrils and can thrive under relatively low light intensities (Radford et al. 1968). With respect to its form and site requirements, this species is very similar to rattan-vine except that its vines do not exhibit the extensive diameter growth of rattan-vine. Because it must derive support from some object in the forest, cross-vine frequently is associated with blown down trees, fence rows, or low growing tree limbs. Also, like rattan-vine, it is typically found on areas of relatively high soil moisture.

The inferences drawn about cross-vine as to its importance to woodcock habitat are quite similar to those for rattan-vine. The substantially higher frequencies on the flushing points indicate that these samples were from shaded, moist sites characterized by some structure capable of supporting a twining growth form. The slightly higher coverage values for the flushing sites suggest that woodcock prefer areas containing a density of cross-vine greater than those typically encountered on the study areas.

8. Grasses (Poaceae): -- All grasses, with the exception of switch-cane, were placed in a family grouping because of difficulty of identification during the winter months. This family was one of the most frequently occurring plant groups on both the flushing points and the random plots and the consistency of the frequency values between

areas is noteworthy (see Tables 4 and 5). Apparently, grasses were distributed somewhat uniformly over all the study areas. This contention is further supported by the coverage data (Table 6) that shows a consistency of values between areas as well as between sampling procedures. Grasses did not offer any specific information on diurnal cover preferences. Had the researchers been able to identify individual species of grasses, more information would probably have been available on site selection.

9. Oaks (*Quercus* spp.): -- Several species of oak were widely and uniformly distributed on the study areas. Since the sampling units (mil-acre) were so small, almost all of the oaks tabulated were seedlings or sprouts and therefore very small. Even if leaves were present on these specimens, the influence of growing in an understory environment distorts the leaf shapes and makes specific identification difficult (Putnam et al. 1960). However, the species of oaks observed in the overstory [primarily water oak (*Quercus nigra*), willow oak (*Q. phellos*), and overcup oak (*Q. lyrata*)] were probably responsible for this regeneration.

Oaks were as common to random plots as they were to flushing points and there was very little difference of coverage values either between areas or between sampling procedures (Tables 4, 5, and 6).

The site requirements for regeneration of bottomland oaks are so broad that no specific site information for their occurrence was obtainable. Discussing the site requirements for bottomland oaks (water oak and overcup oak), Putnam et al. (1960) observed that they are widely distributed on flats and ridges and they regenerate prolifically in either shade or sunlight. They classify these oaks as moderately intolerant species but emphasize the fact that seedlings will persist under shade for several years.

Because almost all oaks sampled were recent regeneration and because these have such broad site requirements, the close adherence of all frequency and coverage data must represent a uniform distribution of this group on all the study areas. These data therefore provided no specific insight into woodcock habitat requirements.

10. Boxelder (*Acer negundo*), Red maple (*Acer rubrum var. drummondii*), and Sugarberry (*Celtis laevigata*): -- The analyses for these three species were so similar that there is no need to discuss them separately. All of these species exhibited frequencies of approximately 30 percent for the flushing points and 10 percent for the random plots on both study areas (see Tables 4 and 5). The coverage values for both study areas were comparable for each species between the random plots and flushing points (see Table 6).

With few exceptions, the site requirements for all three species are very similar. Red maple and sugarberry are very tolerant of shading while boxelder is moderately tolerant. Also, red maple and sugarberry are primarily found in low flats while boxelder typically occurs on higher flats or lower ridges. All three species require moist sites and are opportunistic in that they can persist in the understory for a long time and when light becomes available they grow rapidly (Putnam et al. 1960).

Because site requirements are similar for these three species and the frequency differences so pronounced and constant between flushing points and random plots on both study areas, these species may be indicative of preferred diurnal woodcock cover. Because the sampled area was so small (mil-acre), almost all of the representatives of these species were in the form of seedlings or sprouts, therefore implying that the areas with higher frequencies of these species (flushing points) were shaded. Also, the high soil moisture tolerances of these species indicate that areas in which these species were found more frequently were of a wetter nature than the random or "typical" sites. This contention is supported by the data presented earlier on soil moisture. The coverage data are inconclusive in that they suggest that wherever these plants occur, they tend to distribute themselves in approximately the same patterns. This observation has no apparent application for determining woodcock habitat preferences.

11. Sweetgum (Liquidambar styraciflua): -- This species exhibited a complete reversal of the trend depicted by boxelder, sugarberry, and red maple in that the frequency values for the random plots were about four times the value of the flushing point frequencies (see Tables 4 and 5). The coverage percents, however, were closely correlated between flushing points and random plots on both study areas (see Table 6).

Sweetgum grows on many bottomland sites but makes its best growth on ridges. For reproduction, this species must have openings with substantial sunlight. It is intolerant of shading and will not persist in the understory (Putnam et al. 1960).

The lower frequencies observed on the flushing points suggest that woodcock selected against sites on which sweetgum regeneration was encountered most frequently. The close correlation of the coverage data both between sites and between sampling procedures suggests that sweetgum distributes itself in approximately the same densities wherever it occurs.

By applying the information derived from previous vegetation and soil analyses to the results of the analysis of sweetgum, one must conclude that this species occurs most frequently on sites that are too low in soil moisture and too high in light penetration for optimum woodcock habitat.

Comparisons of total vegetation on each area

Because there seemed to be consistent differences between frequencies and sometimes between coverage values for certain plant species within each area, a comparison of the plant communities as a whole for both random and sample plots seemed appropriate. To test for dispersion differences between the frequency distributions of vegetation on the random plots versus the flushing points, a Chi-square test was used. To test for homogeneity of relative position or agreement between relative rankings of frequency distributions of vegetation on the random plots versus the flushing points, a Spearman Rank Correlation Coefficient was used.

The Chi-square tests showed that there were significant differences in frequencies of plant taxa between random plots and flushing points on both study areas and between the total plots. The Spearman Rank Correlation Coefficients substantiated these findings. There were significant differences between Chi-square values for both study areas as well as the totals, indicating that the ranking of plants on the basis of frequency for the random plots was not related to the ranking on the flushing points (see Table 7).

The results of these two tests provide convincing evidence that woodcock choose diurnal habitats that are composed of significantly

Table 7. Comparison of the frequency of occurrence of plant species on random versus sampled plots on two study areas by means of a Chi-square test and a Spearman rank correlation coefficient.

Chi-square Test	Spearman Rank Correlation Coefficient
Morganza (Area 1)	
X^2 cal. = 109.9*	rs cal. = .799*
X^2 tab. = 26.2	rs tab. = .606
Bayou Choctaw (Area 2)	
X^2 cal. = 58.0*	rs cal. = .851*
X^2 tab. = 38.9	rs tab. = .641
Total	
X^2 cal. = 380.1*	rs cal. = .591*
X^2 tab. = 58.1	rs tab. = .456

*Indicates a difference at $p < .01$ level of significance.

different vegetative characteristics than are random or "typical" areas in bottomland hardwood forests.

Overstory Analyses

Fourteen species of overstory trees were sampled on the 1/100 acre plots from both the flushing points and the random plots. In order to qualify as an overstory tree, each specimen had to have a 9 inch diameter at breast heighth (dbh). For analytical purposes, several species of trees were listed by their genus. Therefore, the four species of oaks [water oak, willow oak, overcup oak, and Nuttall oak], the two species of elms [American elm and winged elm (*Ulmus alata*)], and the three species of hickories [pignut hickory (*Carya glabra*), bitter pecan, and sweet pecan (*C. illinoensis*)] were tallied by their respective genus only. Apart from these three genera, five species of overstory trees were identified from the three study areas.

On each flushing site and random plot, the basal area of the overstory trees was determined. Plots with no overstory trees were omitted from this analysis. The measurements obtained from each sampling technique were tested for differences with a t-test and these results are presented in Table 8. Because of its direct correlation with cubic volume, basal area per acre provides a logical expression of stand density (Avery 1967). Therefore, the significantly higher values for the flushing points on each area suggest that flushes occurred from timbered areas with densities greater than those found on the random or "typical" sites.

An inspection of the frequency data in Table 9 suggests that there is a relationship between woodcock flushes and overstory species.

Table 8. Results of t-tests comparing basal area of trees 9 inches dbh or larger on random plots with those on flushing points.*

Morganza (Area 1)		Bayou Choctaw (Area 2)		Grosse Tete (Area 3)		Total	
Flushing points	Random plots	Flushing points	Random plots	Flushing points	Random plots	Flushing points	Random plots
78.5 ft^2	64.5 ft^2**	82.0 ft^2	74.5 ft^2**	89.5 ft^2	not sampled	83.3 ft^2	69.5 ft^2**

* The basal area values were expanded to a per-acre basis although the samples were 1/100 acre in size.

** Indicates a difference at $p < .05$ level of significance.

Table 9. Comparisons of overstory tree species sampled on random plots from two study areas and flushing points from three study areas.

Percent of 1/100 acre plots in which eight species of overhead trees occurred on three study areas.

	Morganza (Area 1)		Bayou Choctaw (Area 2)		Total (Includes flushing point data from area 3)	
Tree Species	Flushing points	Random plots	Flushing points	Random plots	Flushing points	Random plots
Quercus spp.	42.9%	46.2%	37.8%	42.4%	44.1%	44.8%
Celtis laevigata	32.8	18.4	30.4	17.4	32.2	14.9
Ulmus sp.	15.0	3.7	13.0	3.0	14.5	4.5
Liquidambar styraciflua	3.6	24.1	2.2	14.1	3.2	24.0
Carya spp.	1.4	3.7		1.0	1.1	2.8
Fraxinus pennsylvanica	.7	.6		4.0	.5	2.8
Cornus drummondii		3.7		1.0		2.5
Acer negundo	3.6	.6	6.5		4.3	1.7

XUM

Table 9. (continued)

Average number of trees per plot (on plots that had trees), average height of all overstory trees, and results of t-tests comparing these two measurements for random plots versus flushing points.

	Morganza (Area 1)		Bayou Choctaw (Area 2)		Total (Includes flushing point data from area 3)	
Tree Species	Flushing points	Random plots	Flushing points	Random plots	Flushing points	Random plots
Average Number of trees per plot	4.67*	2.04	3.81*	2.11	4.65*	2.15
Average Height of all trees	32.9 ft*	64.3 ft	36.7 ft*	56.5 ft	41.0 ft*	63.9 ft

*Indicates a difference at $p < .01$ level of significance.

Sugarberry, the elms, and boxelder showed a consistently higher frequency of occurrence on the flushing points than on the random plots. Conversely, sweetgum registered higher frequencies on the random plots. Rather than being indicative of a preference by woodcock for certain overstory species, I believe these differences to be indicative of site preferences. All three of the species that occurred in higher frequencies on the flushing points are considered to be shade tolerant and demanding of a wet site. Sweetgum, which occurred more regularly on the random plots, is intolerant of shade and needs a dryer site to grow well (Putnam et al. 1960).

The data presented for the number of trees per plot show that on those plots that had trees, there were significantly more trees on the flushing point plots than on the random plots.

The height data show that the flushing points had significantly shorter trees than did the random plots on either study area. In this regard, shade tolerant species, which were found to be most abundant on the flushing points, were of a different form or shape than the intolerant species such as sweetgum or most of the oaks. All of the shade tolerant species are susceptible to epicormic branching and poor form when released from light suppression. On the other hand, sweetgum and the oaks, other than overcup oak, generally have a long, fairly clean bole when grown at medium levels of stocking such as those reported in the basal area analysis (Putnam et al. 1960). Therefore, many of the shade tolerant trees, which were classified as overstory trees due to a dbh of 9 inches or larger, were often of poor form with many side limbs. These trees provided substantially more overhead cover than did those specimens with long, clear boles.

The flushing points had almost twice the number of trees per acre as the random plots and because basal area varies with the square of the diameter, the basal area on the flushing points would have been four times that of the random plots had the sampled trees been the same size. The basal area for the flushing points was only about 10 percent larger than that of the random plots; therefore the trees on the flushing points were smaller in diameter than those on the random plots. The data presented for tree height show that the trees on the random plots were significantly taller than the trees on the flushing points. The trees on the random plots were larger in all respects. The frequency data indicate that more shade tolerant trees grew on the flushing points than on the random plots. Also, the trees found on the flushing points were capable of growing on moister sites than were the trees found on the random plots. Therefore the best overstory for woodcock habitat seems to be made up of a patulous, shade tolerant species growing on moist sites. The optimal composition is a dense stand of trees of relatively small diameter.

Other Site Analyses

Although analyses of soil characteristics and plant communities were important to the evaluation of diurnal habitat for woodcock, a description of habitat from these variables alone would be incomplete. Therefore, data regarding site structure (physiognomy) and light intensities of preferred habitat were gathered as a supplement to and for comparison with the data previously described.

Structural site components

All points from which woodcock were flushed or from which random samples were taken were described by one of seven general physiognomical groupings referred to as sample types. These types included switch-cane thickets, blowdowns (trees or limbs lying horizontally on or near the forest floor), blackberry and dewberry thickets, hardwood understory, fencerows, honeysuckle thickets, and greenbrier thickets. The general characteristics of most of these sample types were discussed in the section on vegetation. However, hardwood understory, as used in this context, requires explanation. This term was applied to any plant or group of plants growing in a suppressed condition under a stand of hardwoods and that fit none of the other sample type categories. No sites existed on the timbered portions of any of the three study areas to which one of these categories could not be applied. Random plots and flushing points were compared for differences in distributions of each sample type by means of a Chi-square test.

The total number of flushing points analyzed for this table was 134 although there were a total of 149 flushes recorded in diurnal cover for Morganza (Area 1) and Bayou Choctaw (Area 2). This difference (15 flushes) represents those birds that were believed to have moved from their original resting place prior to flushing. These flushes were not included in this analysis to avoid distorting the data.

The sample types responsible for the significant differences in distributions indicated by the Chi-square value are easily recognizable (see Table 10). The substantially higher frequencies for blackberry and dewberry thickets, switch-cane thickets, and blowdowns on the flushing points and the higher frequency value for the hardwood understory type

Table 10. Frequencies and percentages of each "type" on two study areas and results of a Chi-square test to analyze differences of distributions of "types" between flushing points and random plots.

	Flushing Points		Random Plots	
Type	Frequency	Percent	Frequency	Percent
Switch-cane Thicket	41	31	2	3
Blowdown	27	20	2	3
Blackberry & Dewberry Thicket	37	28	6	9
Hardwood Understory	10	7	52	74
Fencerow	13	9	1	1
Honeysuckle Thicket	5	4	3	4
Greenbrier Thicket	1	1	4	6
Total	134		70	

Flushing Points versus Random Plots: X^2 tab. = 13.28; X^2 cal. = 36.51*

*Reject the hypothesis that the distributions which were compared were the same ($p < .01$).

on the random plots serves to illustrate preference by woodcock for certain types of physiognomy within their diurnal habitat.

Although the data collected for the sample types described the composition of each sampled point, it did not describe the structure. That is, the category titled switch-cane thicket did not specify whether a thicket consisted of a few, small, sparsely distributed stalks of this species or whether it was a dense canebrake with stalks 20 feet tall. In order to describe the structure of the sample sites, density values were assigned to each random plot and flushing point. Although arbitrary, these values were based on ground level density, defined as the density of the material immediately adjacent to the sampled site on the forest floor. A value of 1 was assigned to heavy densities, 2 for medium densities, and 3 for light densities. There were significant differences between random plot densities and flushing point densities for heavy and light densities, but not for medium densities (see Table 11). The significantly higher frequencies for heavy densities on the flushing points and the light densities on the random plots are indicative of a preference by woodcock for sites that are of a dense composition. These findings support the major findings of the vegetational analyses. The lack of significant differences between sampling techniques for the medium densities is probably a reflection of the arbitrariness of the sampling procedure. Recognizing very heavy or very light densities of vegetation was simple, however there was no subjective method for determining where heavy or light densities stopped and where mediun densities began. Therefore, density 2 was something of a catchall category and was used to describe any density that was neither heavy or light. If there were differences in distributions of this

Table 11. Frequencies and percentages of each density value on random and sample plots and results of Analyses of Variance comparing densities between random plots and flushing points.

	Flushing Points							
	Morganza (Area 1)		Bayou Choctaw (Area 2)		Grosse Tete (Area 3)		Total	
Densities	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
1 (Heavy)	46	49	14	30	20	38	80	42
2 (Medium)	27	30	22	48	19	36	68	36
3 (Light)	19	21	10	22	13	24	42	22

	Random Plots					
	Morganza (Area 1)		Bayou Choctaw (Area 2)		Total	
Densities	Frequency	Percent	Frequency	Percent	Frequency	Percent
1 (Heavy)	2	7	2	5	4	6
2 (Medium)	15	50	21	52	36	51
3 (Light)	13	43	17	43	30	43

Results of Analyses of Variance

(1) Comparison of densities between random plots and flushing points for Density 1.
tab. F = 22.67; cal. F = 117.44*

(2) Comparison of densities between random plots and flushing points for Density 2.
tab. F = 10.13; cal. F = 3.61

(3) Comparison of densities between random plots and flushing points for Density 3.
tab. F = 10.13; cal. F = 156.00*

*Reject the hypothesis that the densities were the same ($p < .05$).

density between the two sampling techniques, the nonspecific nature of this category may have been responsible for the inability of the Analysis of Variance to detect them.

Light as a site factor

The results of the analyses of vegetation by species, the densities of vegetation, and the physiognomy of sites associated with woodcock presence suggest that the distribution of woodcock may be related to light intensity, because these factors are all related to light levels in forested environments. The analysis of both light intensity and light reduction was important to the evaluation of diurnal cover in order to determine if woodcock preferred specific light intensities or if they merely preferred certain vegetative types that vary in their light reducing capabilities under various conditions of external light.

The percent of available light was derived by dividing the reflected light value at each sampling site by the total amount of reflected light available at that time. If there was no change in vegetational density from sample to sample, then regardless of the amount of external light, light percentages would remain constant. To minimize the effects of cloud cover or time of day on the correlation analyses of light intensity and habitat type, woodcock flushes were recorded on vegetational type maps according to reflected light intensities. Statistical tests were then used to analyze any changes in distributions under various light conditions.

Intensities of reflected light were measured in foot-candles on random plots and on flushing points and differences between and among areas were analyzed with t-tests. There was a significant difference between Morganza (Area 1) and Bayou Choctaw (Area 2) for the light intensities of the random plots (Table 12). The random samples from Area 1 were taken on a cloudless day while the samples from Area 2 were taken on a day that was partly cloudy. Differences of cloud conditions are verified as the source of the significant difference by Table 13, which shows the percent of available light to be comparable between the two areas. In other words, there was no appreciable difference for the light reducing capabilities of the vegetation for the random plots between the two areas.

The comparisons between the flushing points showed no differences in light intensity between areas. When one considers that these measurements were made over a 3 year period and during widely diverse external light conditions, the closeness of these values is remarkable. Woodcock are apparently quite selective for specific light intensities. This selectivity means that during periods of low external light, sparser cover was chosen than during periods of brighter light. This trend was not detectable by the analyses of flushing points for percentage of available light (Table 13) because these values are means and reflect the average of a broad range of conditions. Because the flushing point samples were taken during almost every conceivable condition of external light during the 3 year study, and because the light intensities between flushing points remained relatively constant, the percentages of available light were highly variable between flushing sites. Considering this variability, the closeness of the mean light percentages between areas is noteworthy. These data suggest that optimum woodcock cover should have such a diversity of vegetation densities that it is capable of averaging an approximate 70 percent light reduction regardless of climatic or temporal variation.

Table 12. Results of t-tests comparing reflected light (in foot-candles) between random plots on two study areas, flushing points on three areas, and between random plots and flushing points on two study areas.

Random Plots

Morganza (Area 1)	Bayou Choctaw (Area 2)	Total
$\bar{x}$ = 16.84	$\bar{x}$ = 12.04	$\bar{x}$ = 15.91
σ = 4.96	σ = 3.62	σ = 5.63

t-test for Area 1 compared to Area 2

d.f. = 68	t cal. = 12.49	t tab. = 1.99*

Flushing Points

Morganza (Area 1)	Bayou Choctaw (Area 2)	Grosse Tete (Area 3)	Total
$\bar{x}$ = 4.42	$\bar{x}$ = 4.32	$\bar{x}$ = 4.50	$\bar{x}$ = 4.41
σ = .12	σ = .10	σ = .13	σ = .19

t-test for Area 1 compared to Area 2		
d.f. = 147	t cal. = .482	t tab. = 1.96
t-test for Area 1 compared to Area 3		
d.f. = 152	t cal. = .376	t tab. = 1.96
t-test for Area 2 compared to Area 3		
d.f. = 99	t cal. = .78	t tab. = 1.96

Random Plots Compared to Flushing Points

t-test for random plots compared to flushing points on Area 1		
d.f. = 129	t cal. = 118.49	t tab. = 1.96*
t-test for random plots compared to flushing points on Area 2		
d.f. = 86	t cal. = 47.61	t tab. = 1.98*
t-test for total random plots compared to total flushing points		
d.f. = 270	t cal. = 70.05	t tab. = 1.96*

*Indicates significant difference at $p < .05$ confidence level.

Table 13. Percent of total available reflected light at random plots and woodcock flushing sites on three bottomland hardwood study areas.

Average percent of the total available reflected sunlight measured at each random plot		
Area 1	93.4%	d.f. = 30
Area 2	87.5%	d.f. = 40
Total	90.4%	d.f. = 70

Average percent of the total available reflected sunlight measured at each flushing site		
Area 1	31.1%	d.f. = 101
Area 2	27.5%	d.f. = 48
Area 3	32.3%	d.f. = 53
Total	30.8%	d.f. = 202

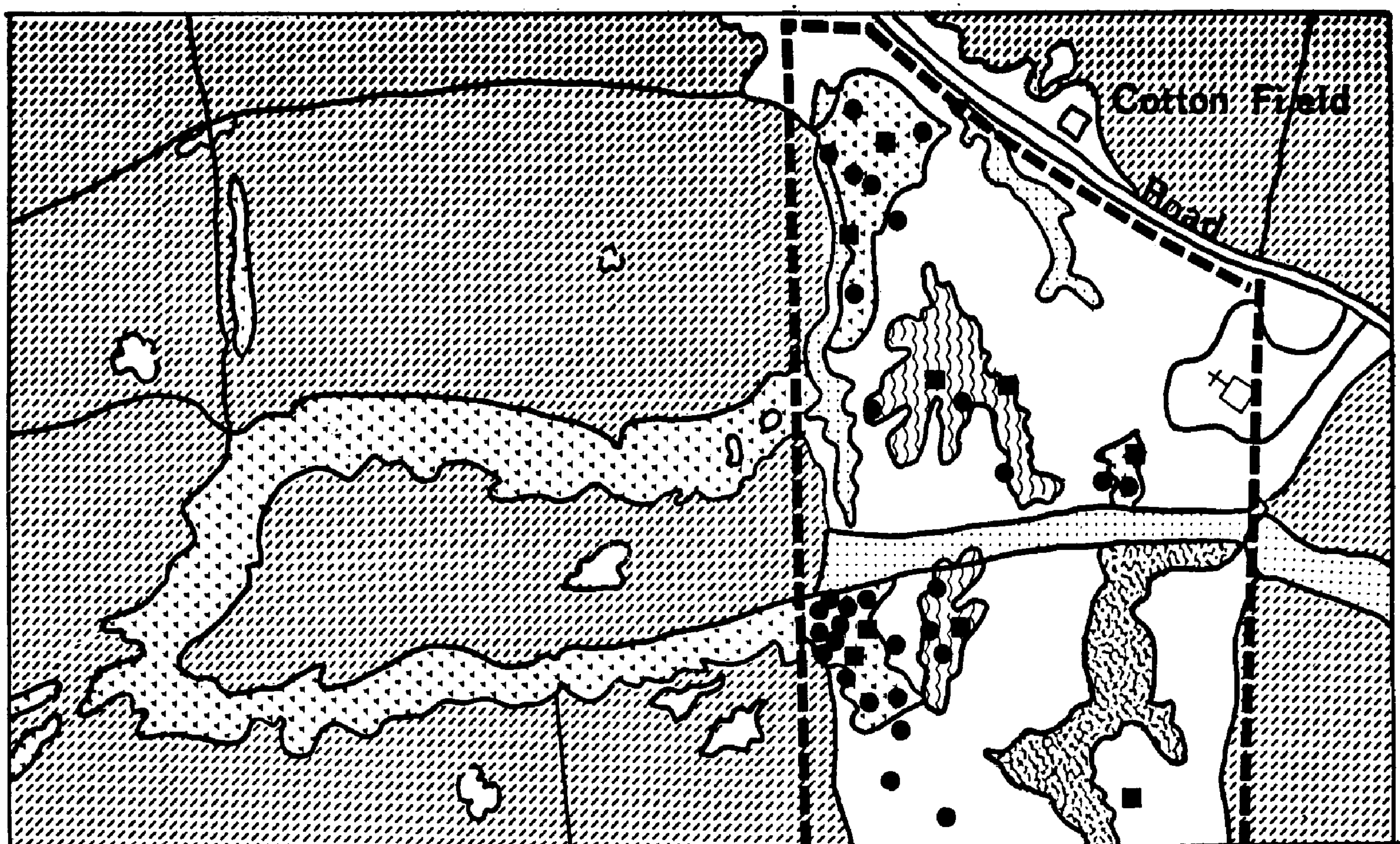
The comparisons between the light intensities on the random plots and the flushing points all proved to be significantly different. Woodcock exhibited a consistent pattern of selecting areas of substantially lower light intensities than those found on the random or "typical" sites.

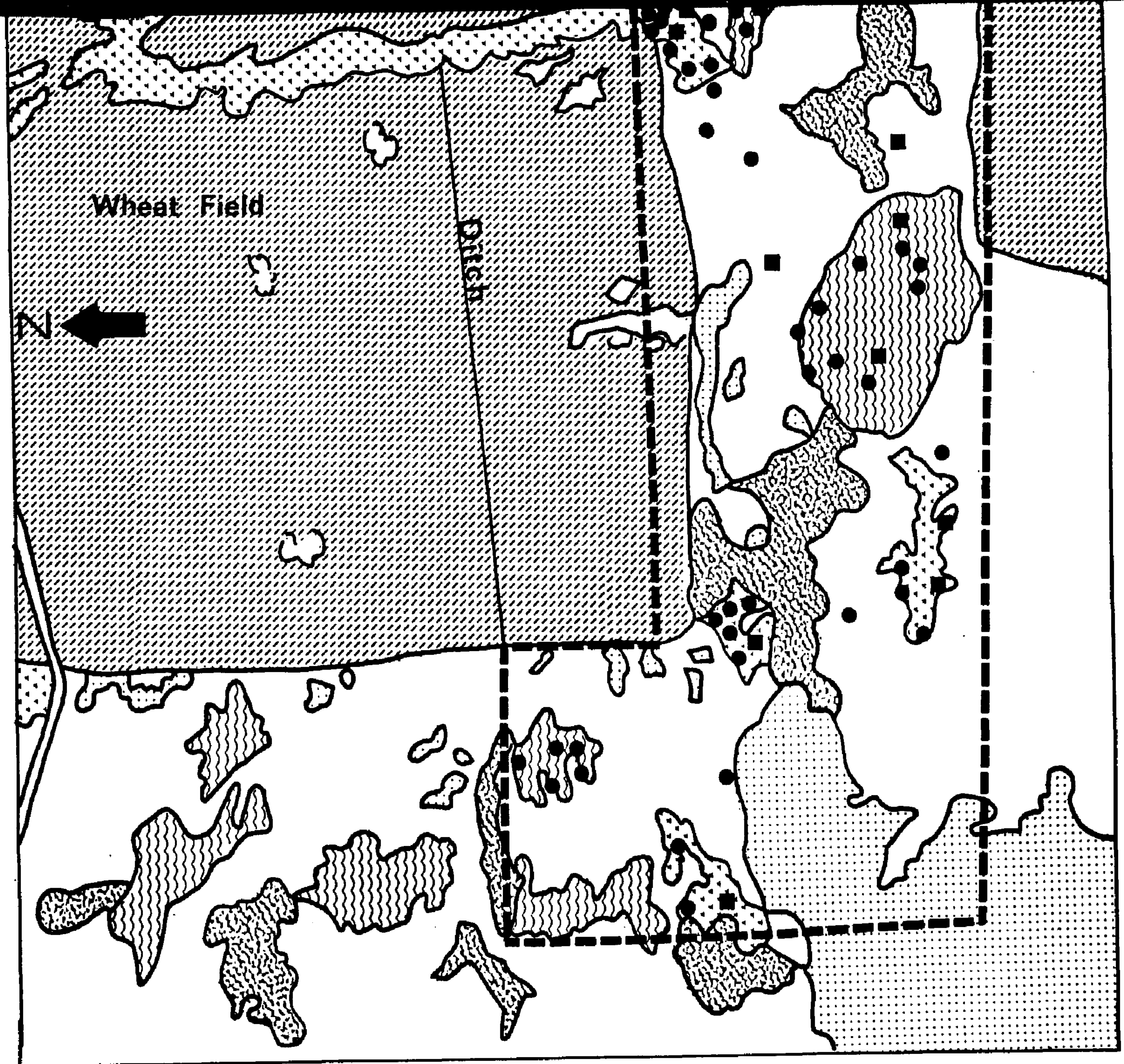
Relationships between habitat and light intensities

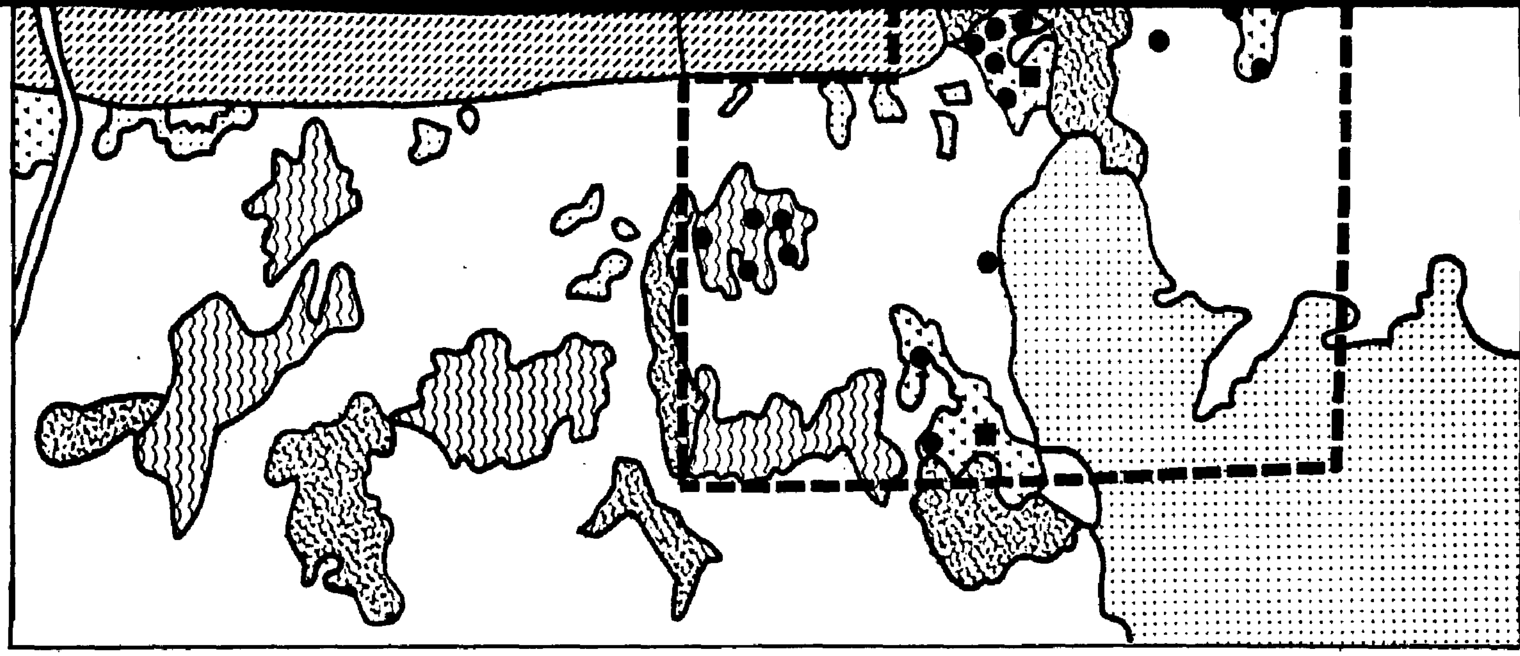
Woodcock demonstrated a preference for certain types of vegetation, a certain site structure for diurnal habitat, and a selection for specific light intensities. To allow broad conclusions to be drawn about habitat selection, however, a more generalized approach to the analysis of habitat selection was necessary. This approach involved mapping each of the three study areas as to its gross vegetational constitution and then plotting each flushing site on these maps. Flushes occurring during periods of bright light (9.5 foot-candles or more of reflected light) were distinguished from flushes during periods of low light (less than 9.5 foot-candles of reflected light) so that any distributional changes caused by external light could be recognized. To quantify any changes of distribution noted on the cover maps, percentages of flushes within each vegetational type were calculated for both light categories and compared to one another and to the overall distribution of vegetation on each study area. To compare the distribution of total flushes under bright light conditions to the distribution of flushes under low light conditions, a Chi-square test was used.

1. Morganza (Area 1): -- Fig. 17 shows the distribution of flushes on Area 1 during periods of bright light while Fig. 18 shows the distribution of flushes during low light conditions. Flushes are concentrated more around switch-cane thickets and heavy timber during periods

Figure 17. Distribution of woodcock flushes over a 3 year period on Area 1 (Morganza) during periods of bright external light.


Cotton Field
Road


Wheat Field
Ditch
N



BOUNDARY OF STUDY AREA

FLUSHES ON INTERMITTENTLY CLOUDY DAYS

FLUSHES ON BRIGHT DAYS

TYPE 1 SWITCH-CANE THICKET

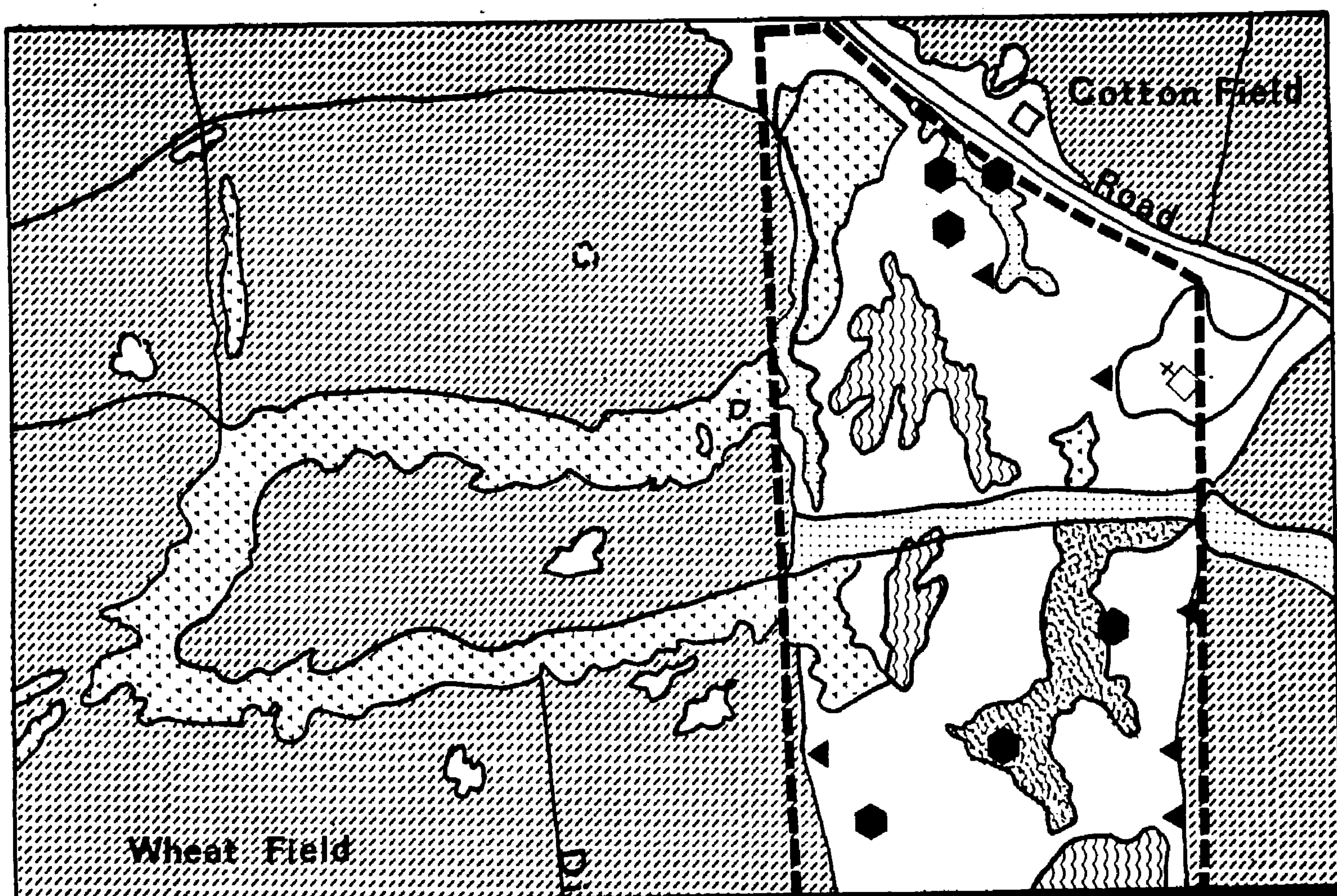
TYPE 2 HEAVY TIMBER

TYPE 3 RECENTLY CUTOVER AREA OR OPENING

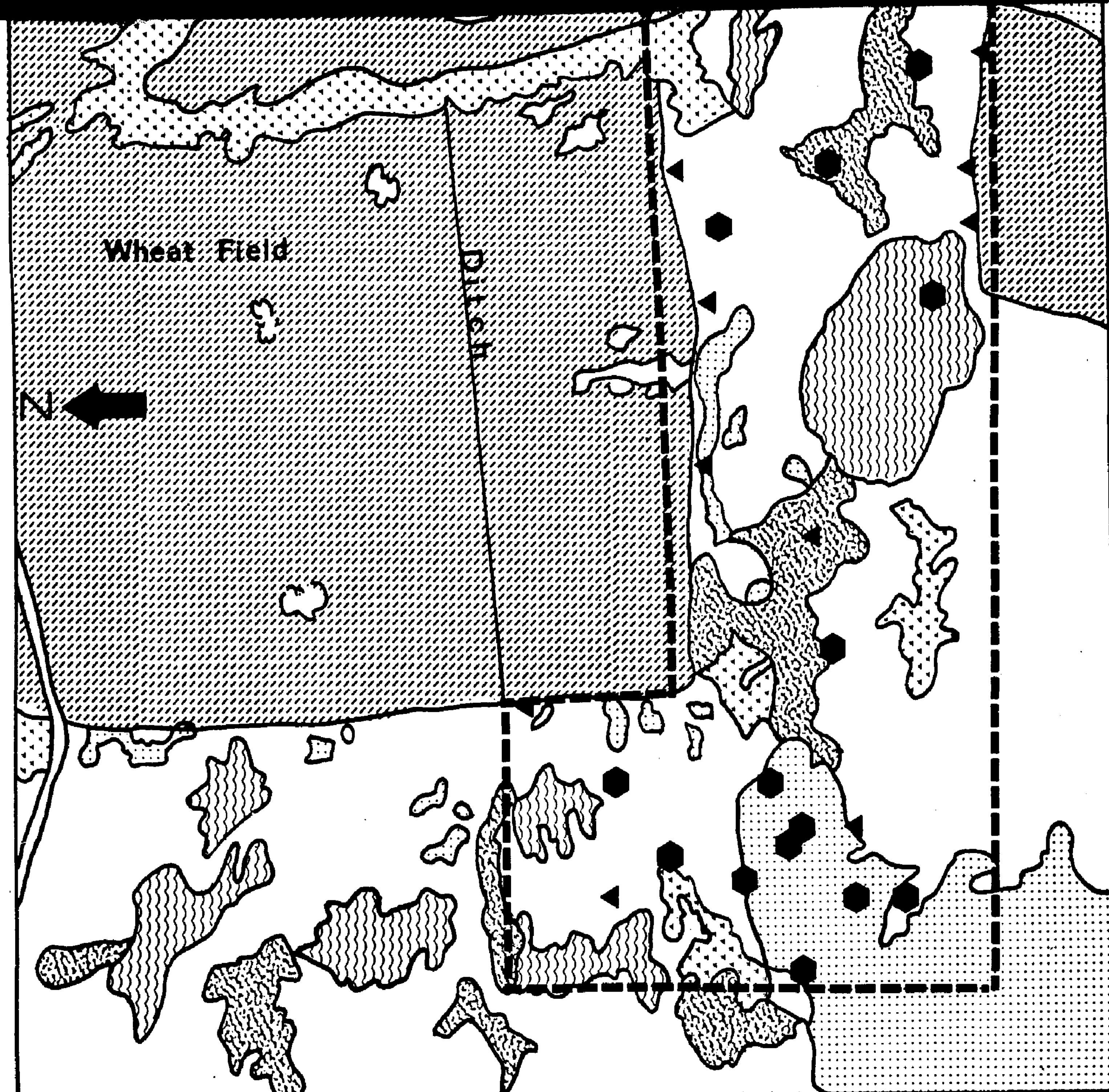
TYPE 4 MODERATELY OPEN TIMBER

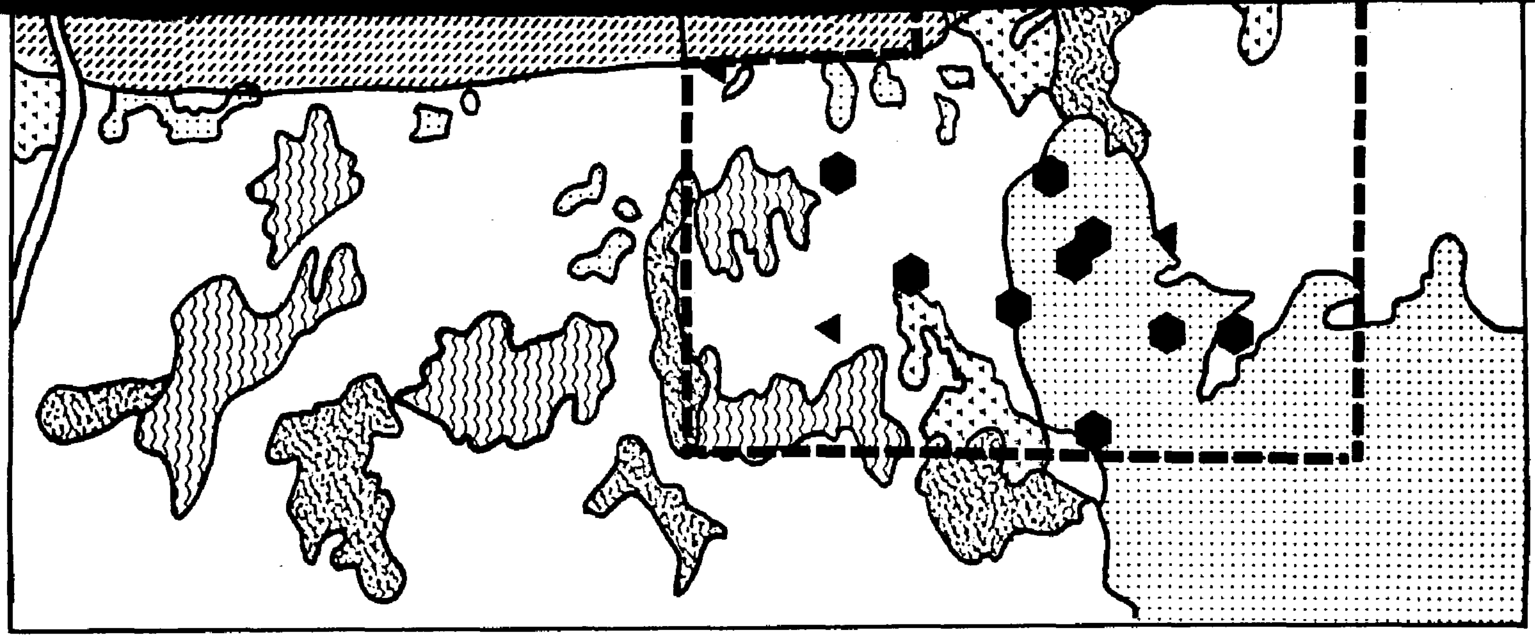
TYPE 5 MODERATELY HEAVY TIMBER

Figure 18. Distribution of woodcock flushes over a 3 year period on Area 1 (Morganza) during periods of low external light.



Cotton Field
Road
Wheat Field


Wheat Field
Ditch
N



BOUNDARY OF STUDY AREA

FLUSHES DURING LATE EVENING OR EARLY MORNING

FLUSHES ON CLOUDY DAYS

TYPE 1 - SWITCH-CANE THICKET

TYPE 2 - HEAVY TIMBER

TYPE 3 - RECENTLY CUTOVER AREA OR OPENING

TYPE 4 - MODERATELY OPEN TIMBER

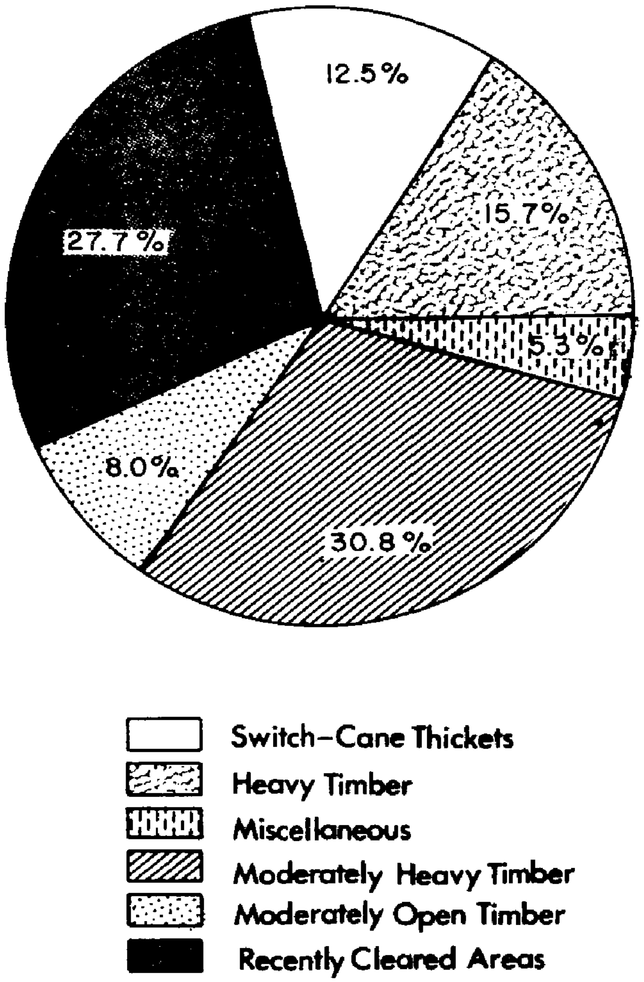
TYPE 5 - MODERATELY HEAVY TIMBER

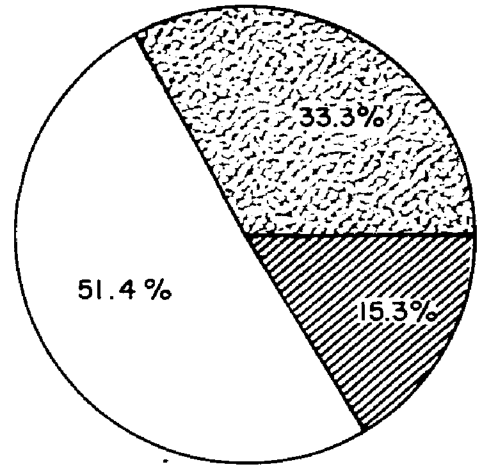
of bright light and around cutover areas or openings during low light periods. These changes in distribution are displayed by percentages in Fig. 19. Although only 12.5 percent of Area 1 is covered by switch-cane thickets, 51.4% of the flushes occurred in these thickets when light was 9.5 foot-candles or brighter. When reflected light intensities were below 9.5 foot-candles, only 3% of the flushes came from switch-cane thickets. The same trend can be identified for the heavy timber category and the antithesis of this trend is illustrated by recently cleared areas and areas of moderately heavy timber.

2. Bayou Choctaw (Area 2): -- Figs. 20 and 21 show the respective distributions of flushes during periods of bright and low light. Although not as definitive as the data for Area 1, these maps show distributional changes between the two light intensities. There are concentrations of flushes around dewberry or blackberry thickets and in areas of heavy timber during periods of bright light and around openings during periods of low light. The graphic representation of these observations is presented in Fig. 22. Blackberry and dewberry thickets occupied 21 percent of the study area, but accounted for 60 percent of the flushes during periods of bright light. During periods of low light, blackberry and dewberry thickets were used as cover in proportions equal to their abundance in the environment. As mentioned previously, these thickets frequently occur in varying densities so that the usage during periods of low light may have been of portions of these thickets that were rather sparse. The data presented previously on density preferences substantiates this hypothesis. The trends exhibited by the flushes in areas of heavy timber during bright light and in cleared areas during low light are the same as observed for Area 1.

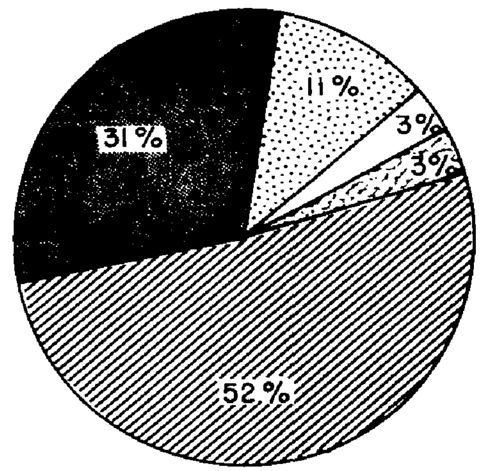
Figure 19. Vegetational types (by percent) on Area 1 (Morganza) and a comparison of flushes during high and low light intensities for each vegetational type.

Percent Coverage by Each Vegetational Type on Area I



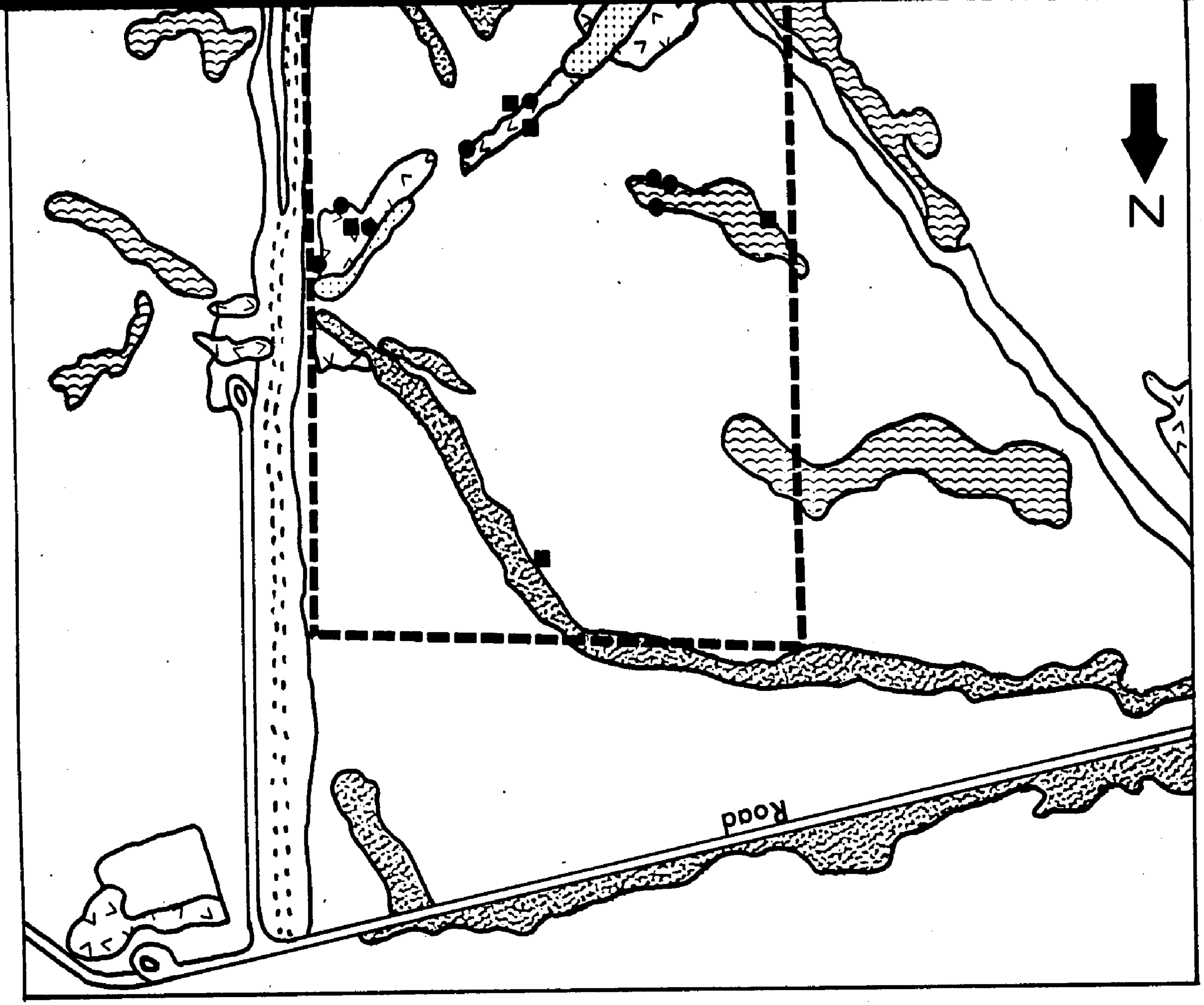


Percent of Flushes Within Each Vegetational Type (Light Intensities of 9.5 f.c. or Greater)

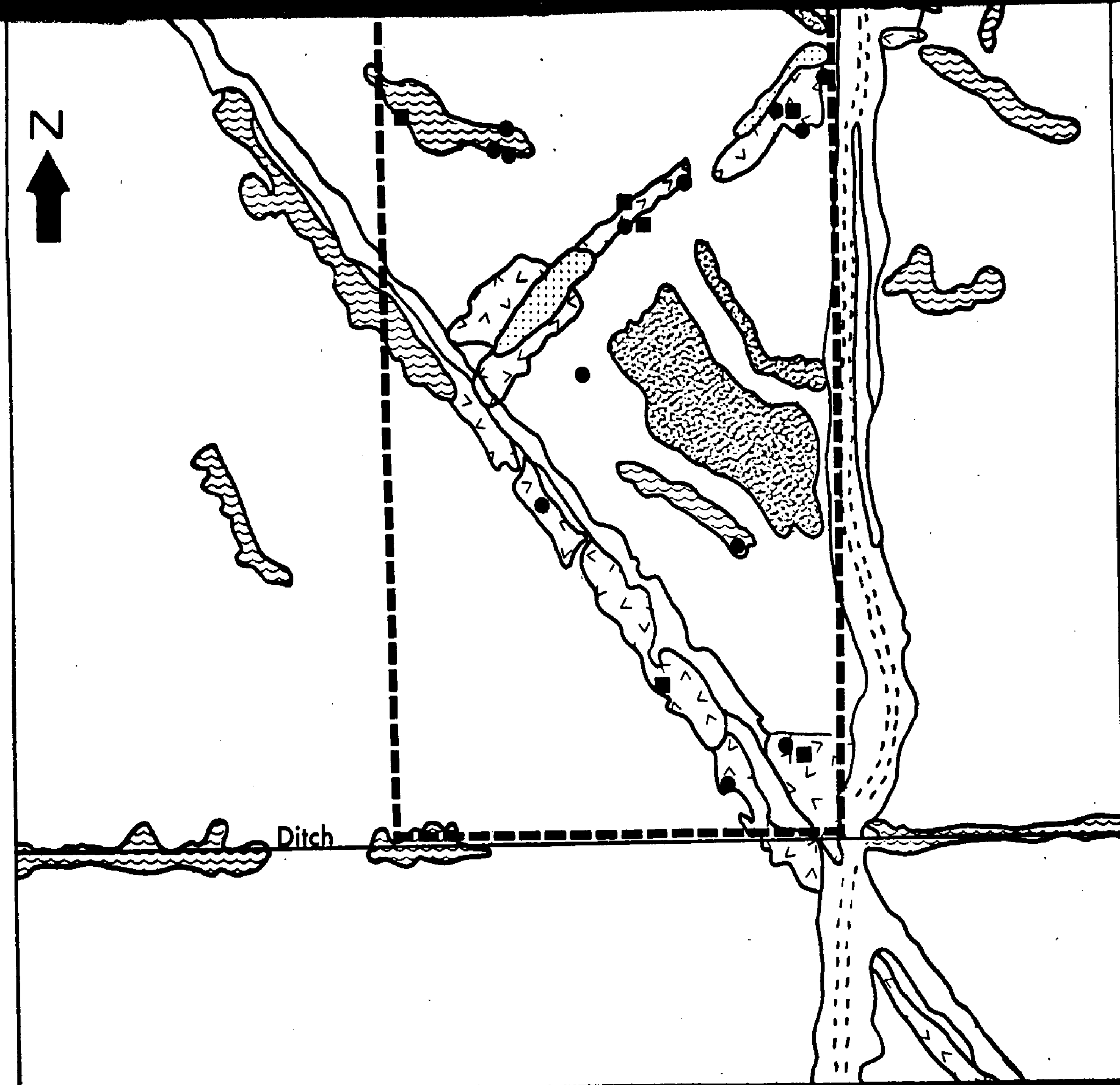


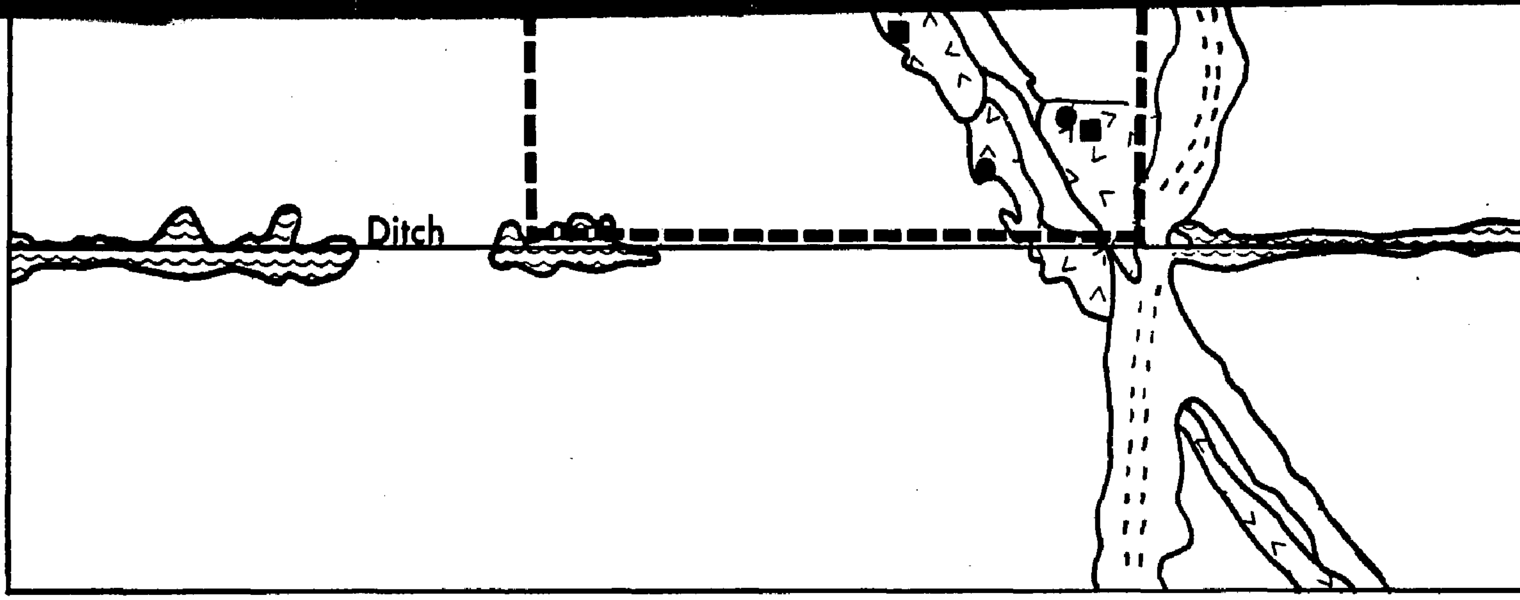
Percent of Flushes Within Each Vegetational Type (Light Intensities of Less Than 9.5 f. c.)

Figure 20. Distribution of woodcock flushes over a 3 year period on Area 2 (Bayou Choctaw) during periods of bright external light.



N
Road


N
Ditch



BOUNDARY OF STUDY AREA

FLUSHES ON INTERMITTENTLY CLOUDY DAYS

FLUSHES ON BRIGHT DAYS

TYPE 2 - HEAVY TIMBER

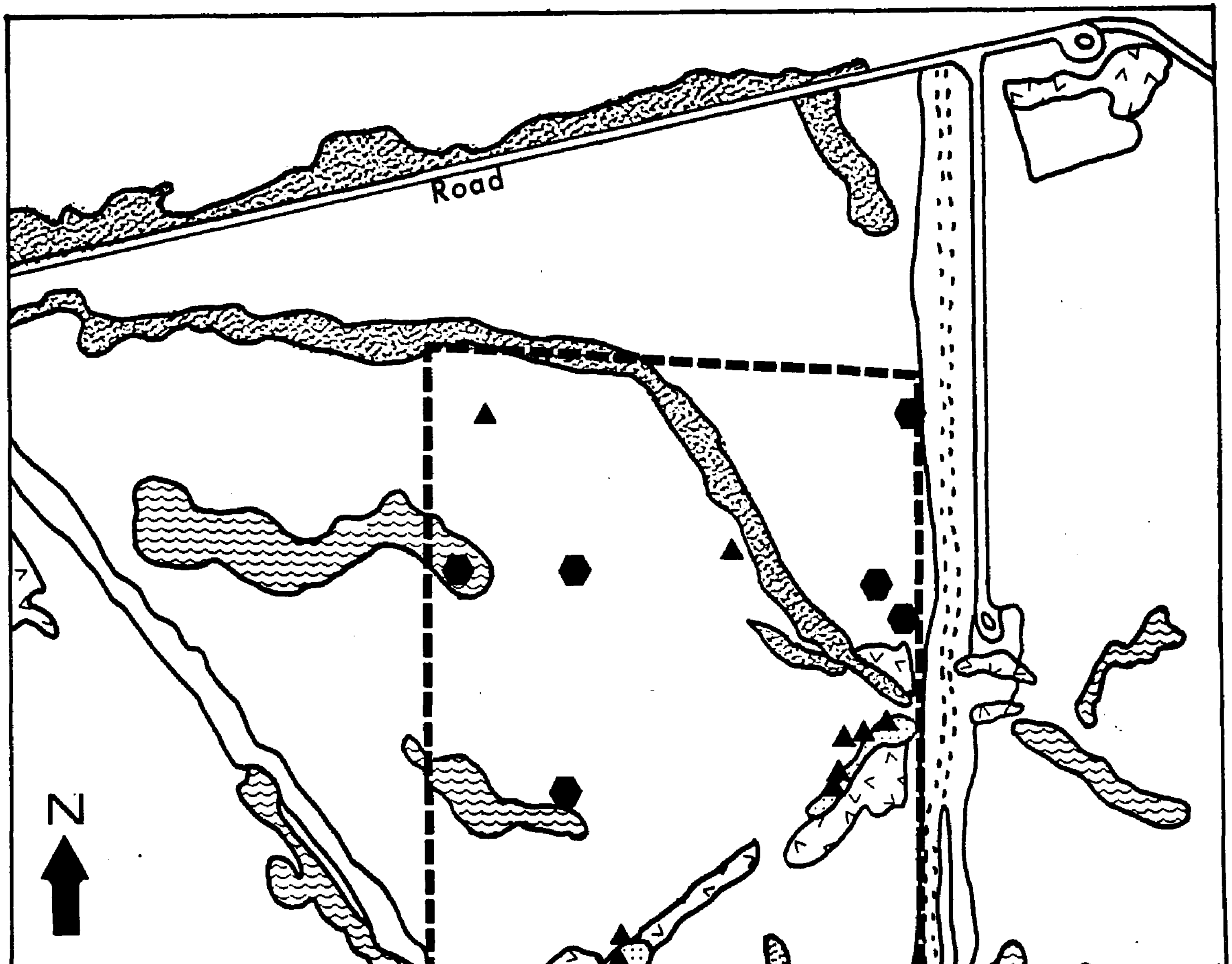
TYPE 3 - RECENTLY CUTOVER AREA OR OPENING

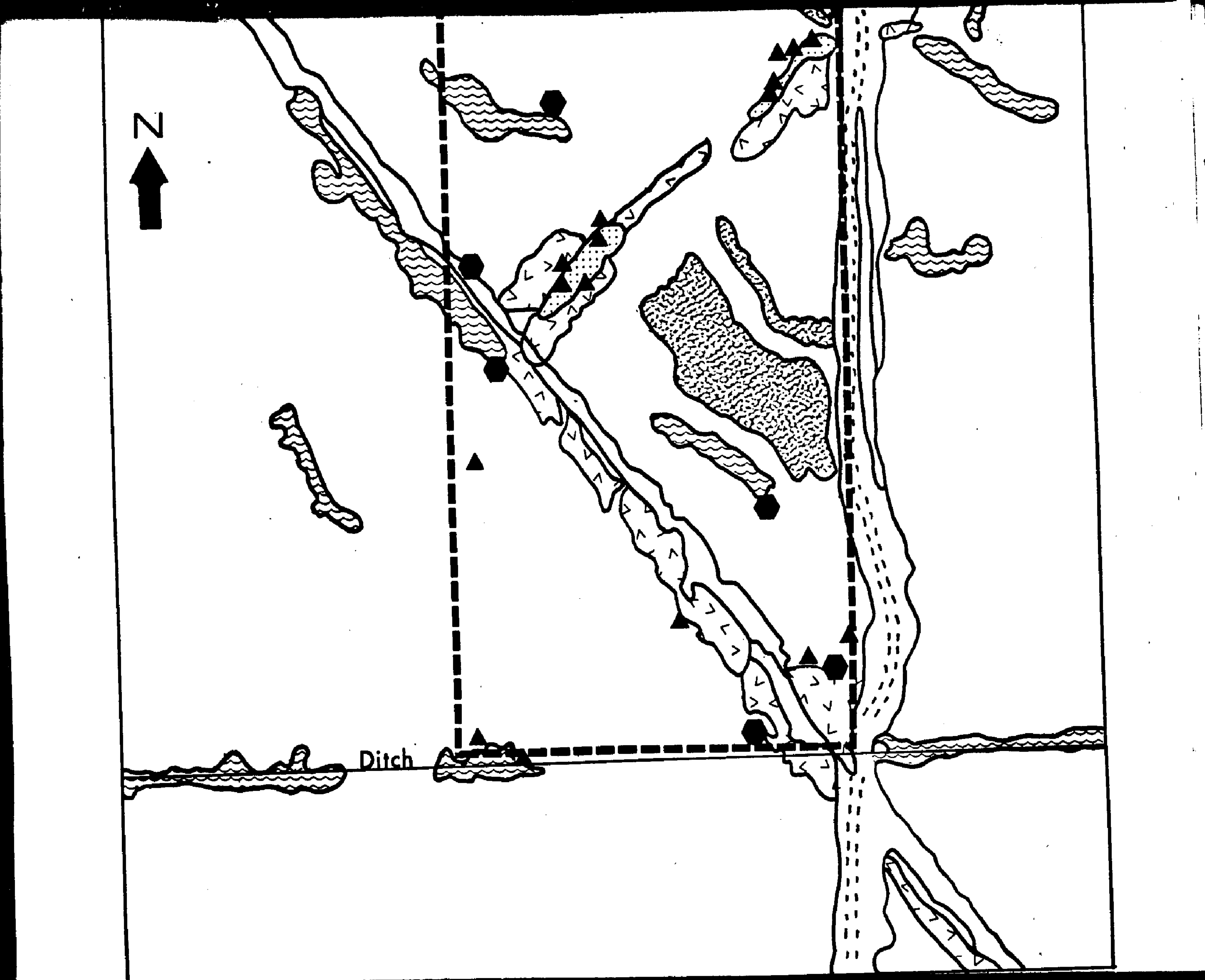
TYPE 4 - MODERATELY OPEN TIMBER

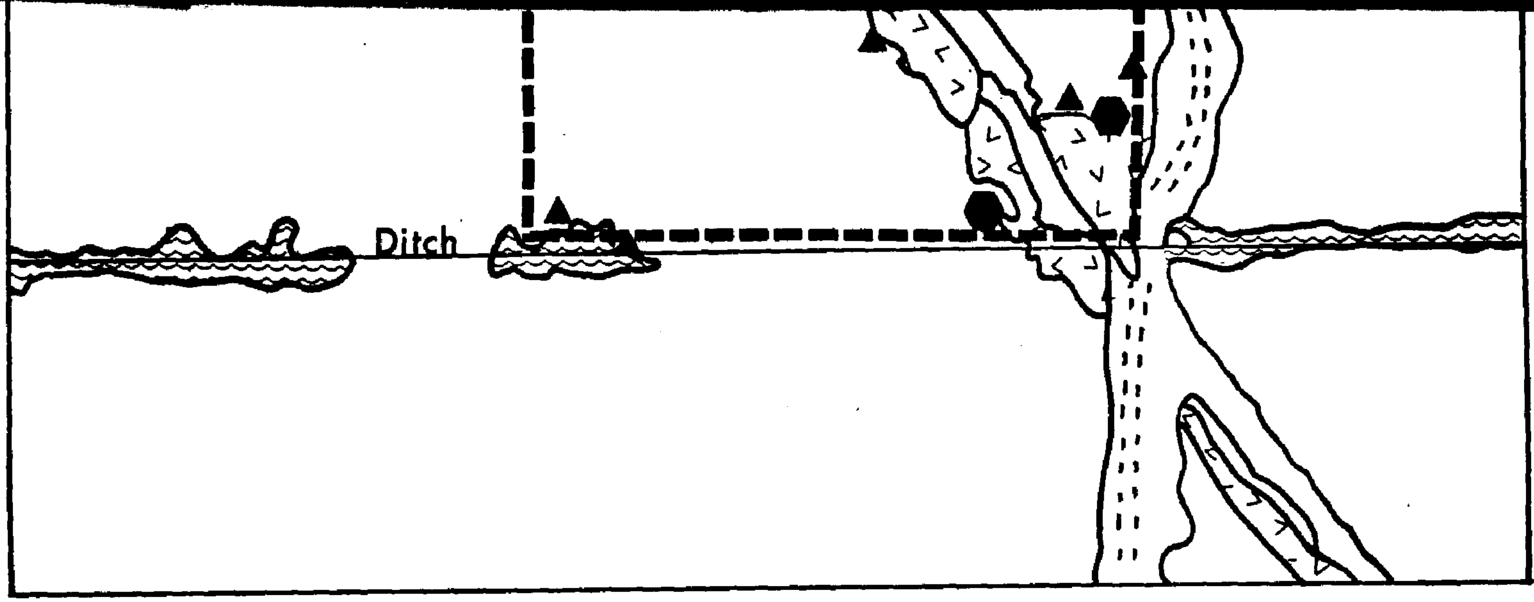
TYPE 5 - MODERATELY HEAVY TIMBER

TYPE 6 - DEWBERRY OR BLACKBERRY THICKET

Figure 21. Distribution of woodcock flushes over a 3 year period on Area 2 (Bayou Choctaw) during periods of low external light.


Road
N


N
Ditch



BOUNDARY OF STUDY AREA

FLUSHES DURING LATE EVENING OR EARLY MORNING

FLUSHES ON CLOUDY DAYS

TYPE 2 - HEAVY TIMBER

TYPE 3 - RECENTLY CUTOVER AREA OR OPENING

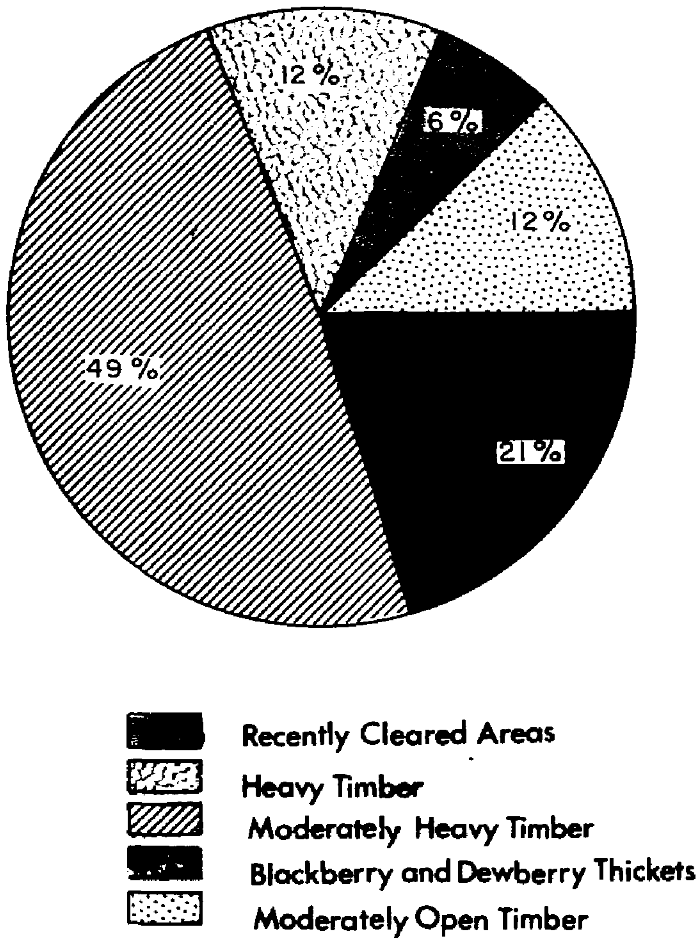
TYPE 4 - MODERATELY OPEN TIMBER

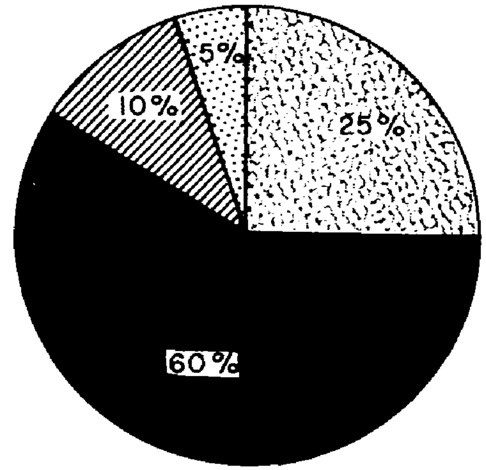
TYPE 5 - MODERATELY HEAVY TIMBER

TYPE 6 - DEWBERRY OR BLACKBERRY THICKET

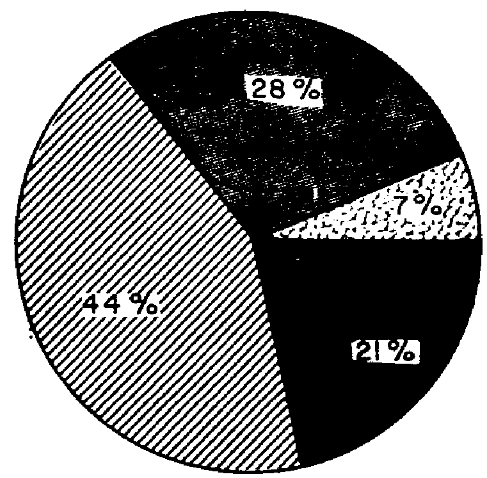
Figure 22. Vegetational types (by percent) on Area 2 (Bayou Choctaw) and a comparison of flushes during high and low light intensities for each vegetational type.

Percent Coverage by Each Vegetational Type on Area 2





Percent of Flushes Within Each Vegetational Type (Light Intensities of 9.5 f.c. or Greater)

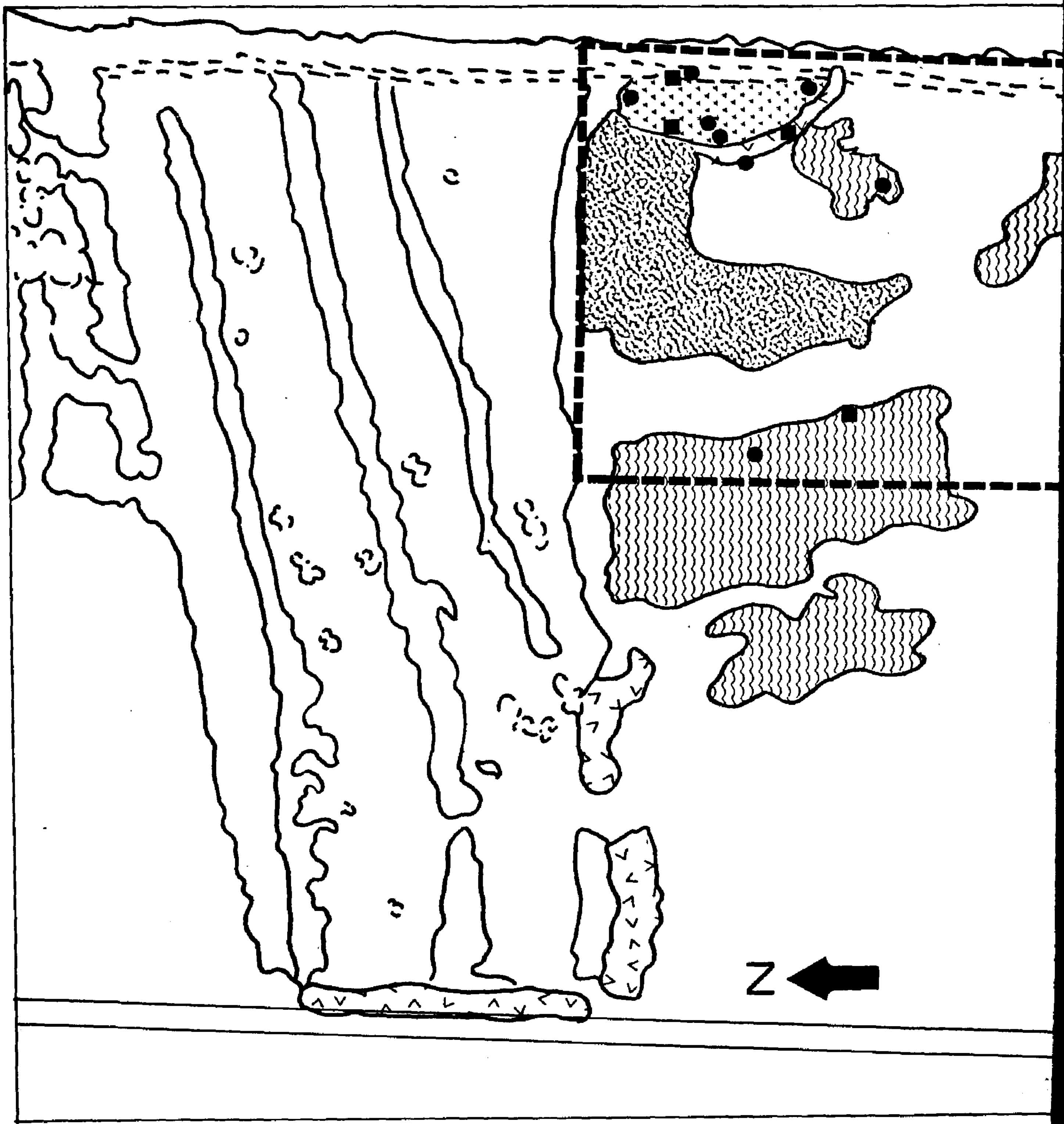


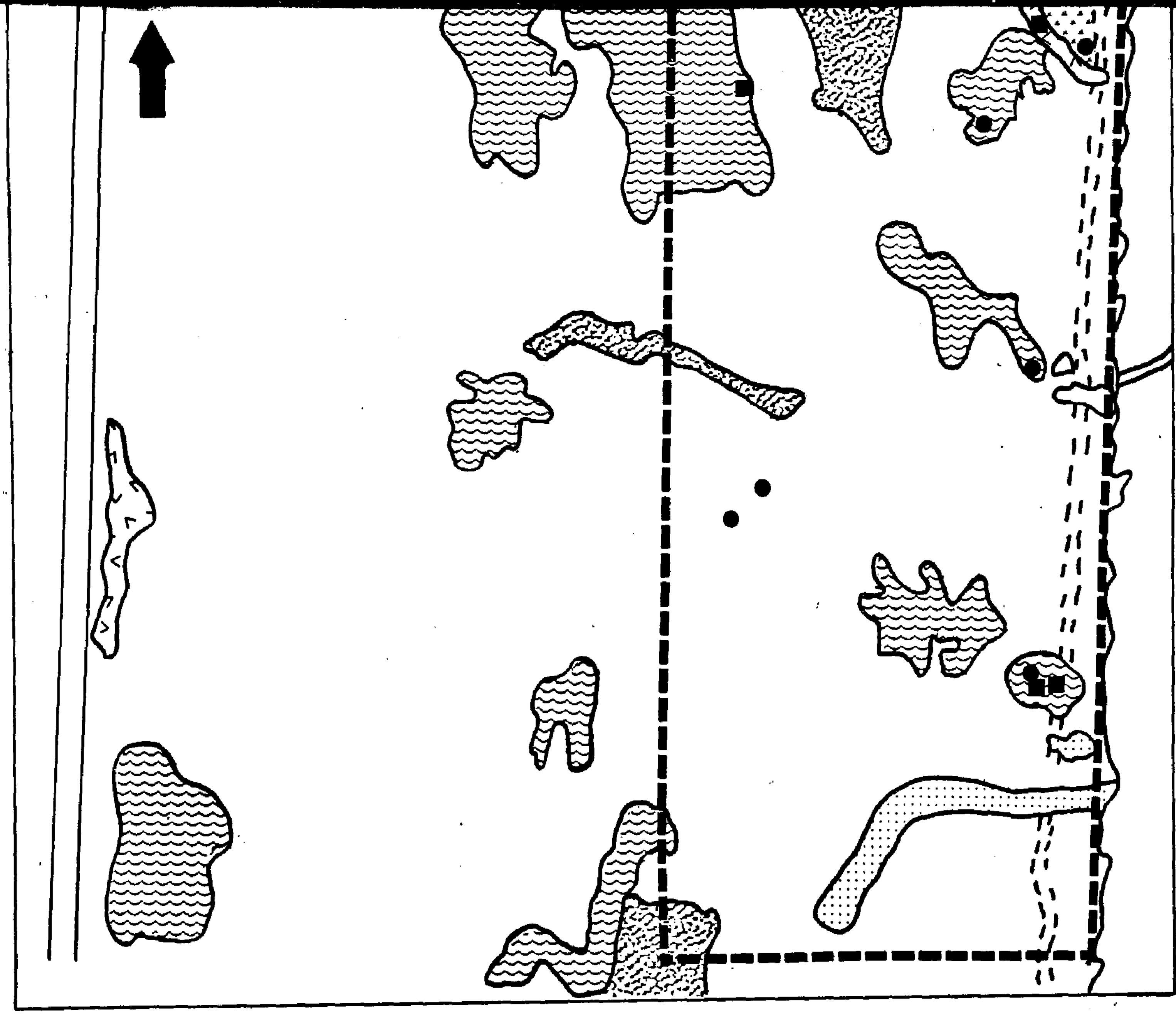
Percent of Flushes Within Each Vegetational Type (Light Intensities of Less Than 9.5 f.c.)

3. Grosse Tete (Area 3): -- The distributions of flushes during periods of bright light are illustrated in Fig. 23 while the low light distributions are given in Fig. 24. The same generalized trends recognized for Areas 1 and 2 can be seen in these figures. There is a concentration of flushes around switch-cane thickets, heavy timber, and blackberry and dewberry thickets during periods of bright light and around openings and moderately open timbered areas during periods of low light. These observations are substantiated by the graphic presentation of Fig 25. The conclusions that can be drawn from this illustration are almost identical to those drawn for the other two study areas.

There is an interesting relationship on Area 3 between switch-cane thickets and blackberry and dewberry thickets. As mentioned in the section on vegetation analysis, Area 1 had relatively high frequency and density values for blackberry and dewberry, however due to soil factors, overstory density and the activity of livestock, Rubus spp. never grew in clearly identifiable thickets such as those found in Area 2. Therefore this species was not recognized as a cover type on Figs. 17 or 18. Area 2 on the other hand, had little switch-cane due to the lack of the proper soil type. Because switch-cane was used so heavily as diurnal habitat on Area 1 and blackberry and dewberry thickets so heavily on Area 2, they were both important constituents of optimum woodcock habitat, but the relative value of each was unknown. However, the cover type analysis of Area 3 provides information as to the comparative value of these two vegetational types. Each of these types accounted for 6 percent of the vegetation on Area 3. However, switch-cane thickets accounted for 39 percent of the flushes under bright light

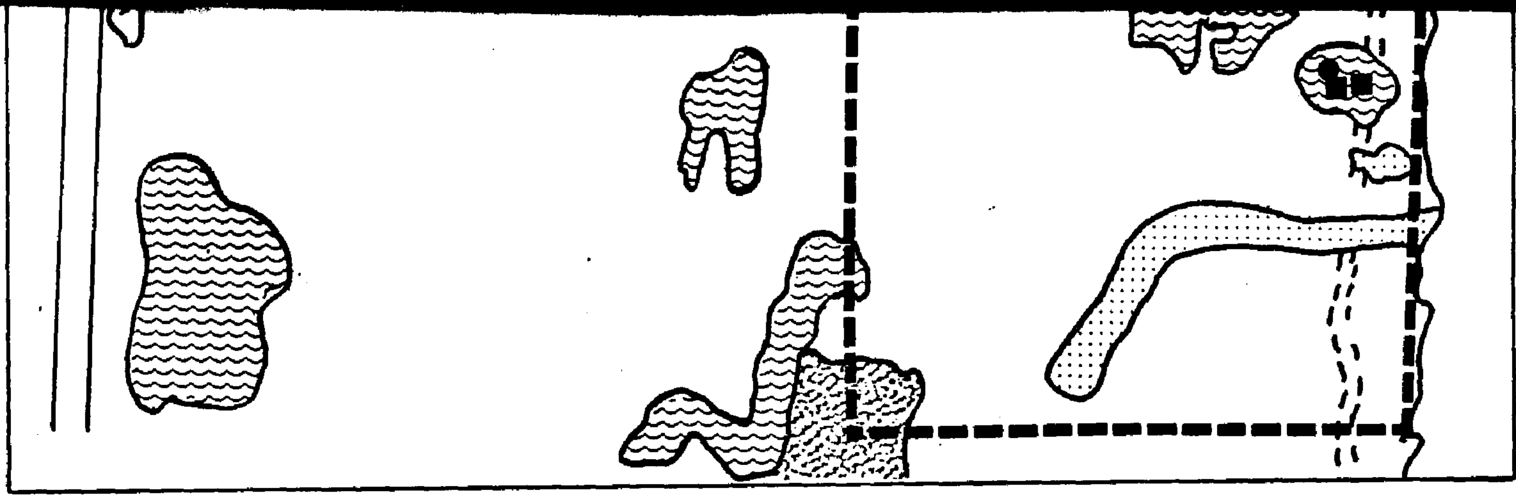
Figure 23. Distribution of woodcock flushes over a 3 year period on Area 3 (Grosse Tete) during periods of bright external light.





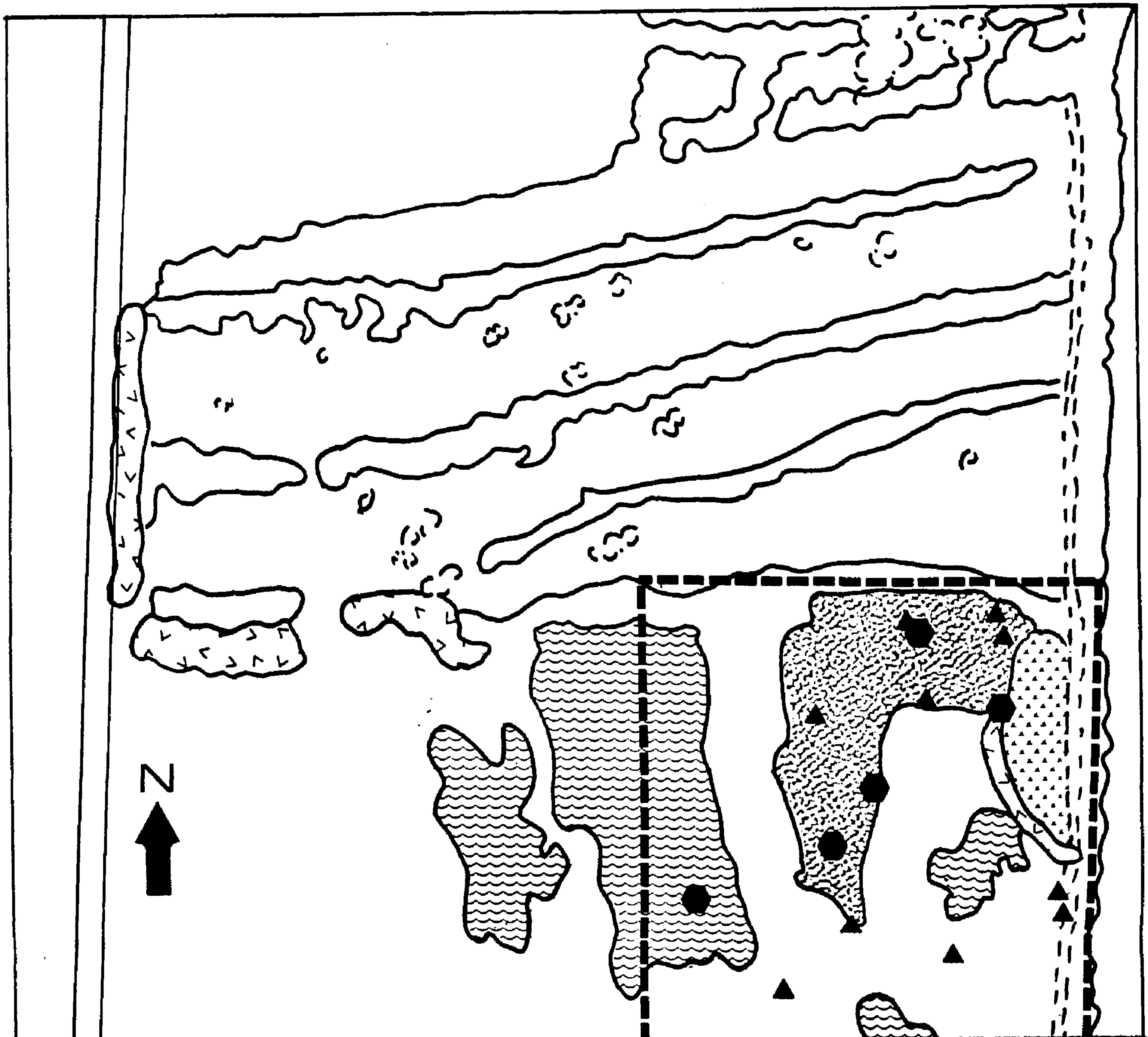
BOUNDARY OF STUDY AREA

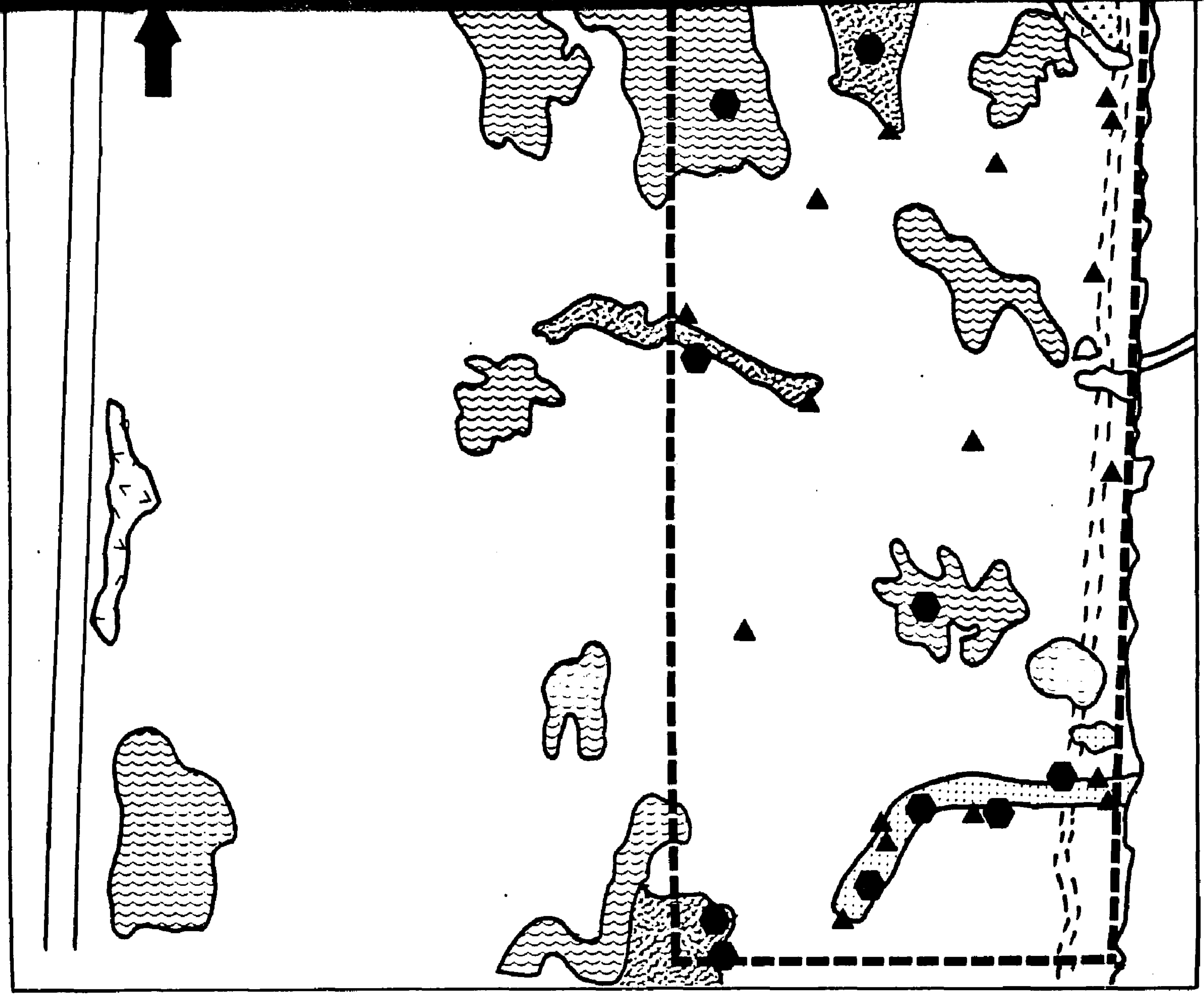
FLUSHES ON INTERMITTENTLY CLOUDY DAYS



- BOUNDARY OF STUDY AREA
- FLUSHES ON INTERMITTENTLY CLOUDY DAYS
- FLUSHES ON BRIGHT DAYS
- TYPE 1 - SWITCH-CANE THICKET
- TYPE 2 - HEAVY TIMBER
- TYPE 3 - RECENTLY CUTOVER AREA OR OPENING
- TYPE 4 - MODERATELY OPEN TIMBER
- TYPE 5 - MODERATELY HEAVY TIMBER
- TYPE 6 - DEWBERRY OR BLACKBERRY THICKET

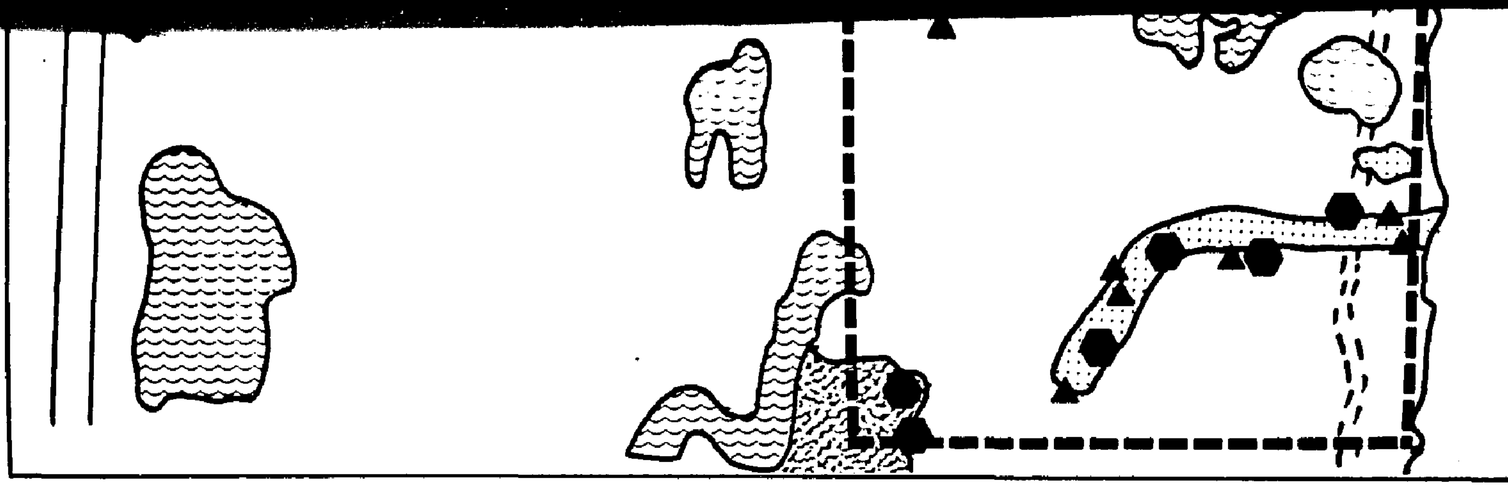
Figure 24. Distribution of woodcock flushes over a 3 year period on Area 3 (Grosse Tete) during periods of low external light.


N



BOUNDARY OF STUDY AREA

▲ FLUSHES DURING LATE EVENING OR EARLY MORNING



- - - BOUNDARY OF STUDY AREA

▲ FLUSHES DURING LATE EVENING OR EARLY MORNING

⬣ FLUSHES ON CLOUDY DAYS

TYPE 1 - SWITCH-CANE THICKET

TYPE 2 - HEAVY TIMBER

TYPE 3 - RECENTLY CUTOVER AREA OR OPENING

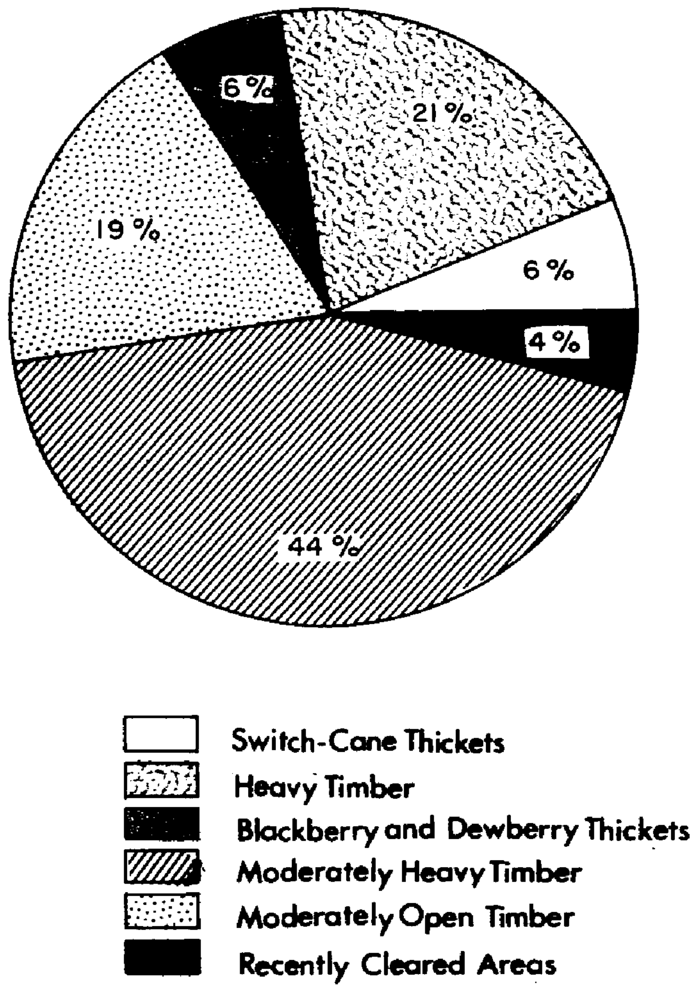
TYPE 4 = MODERATELY OPEN TIMBER

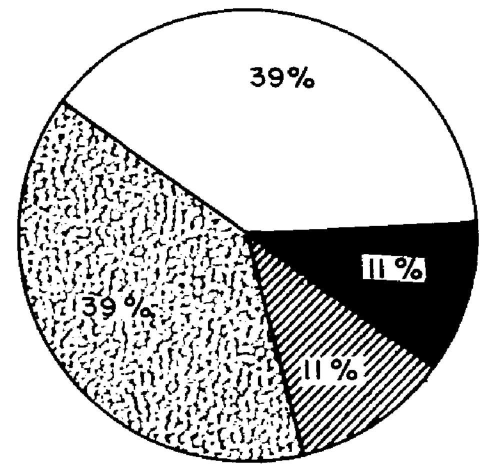
TYPE 5 - MODERATELY HEAVY TIMBER

TYPE 6 - DEWBERRY OR BLACKBERRY THICKET

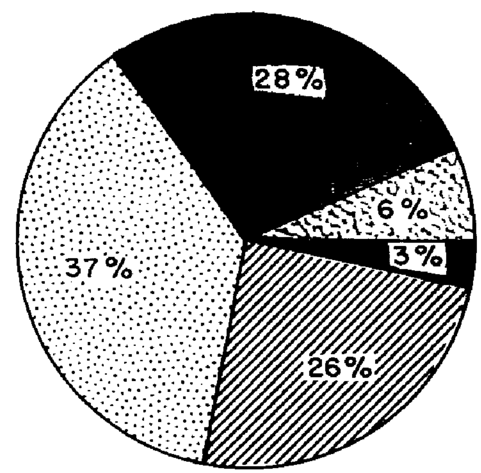
Figure 25. Vegetational types (by percent) on Area 3 (Grosse Tete) and a comparison of flushes during high and low light intensities for each vegetational type.

Percent Coverage by Each Vegetational Type on Area 3





Percent of Flushes Within Each Vegetational Type (Light Intensities of 9.5 f. c. or Greater)



Percent of Flushes Within Each Vegetational Type (Light Intensities of Less Than 9.5 f. c.)

conditions and blackberry and dewberry accounted for only 11 percent. Apparently switch-cane thickets are preferred as diurnal habitat over blackberry and dewberry thickets where these two cover types occur together. The flushing data for low light intensities shows that switch-cane thickets were not used at all while blackberry and dewberry thickets accounted for only 3 percent of the flushes. These data indicate that both these types are equally unimportant during periods of low light intensities.

Comparison of total flushes

A Chi-square test was used to compare the distributions of flushes by each vegetation type under both high and low light intensities. The differences between flushing percentages for each vegetation type are indicative of the sources of variation responsible for the significant Chi-square value (Table 14). The higher percentages for heavy timber and switch-cane thickets under bright light intensities and for cutover areas and moderately heavy timber under low light intensities were obviously responsible for the significant Chi-square value. The closeness of the frequencies between the two light intensities for blackberry and dewberry thickets is probably due to the varying density this vegetative type exhibits. Ideal light intensities can probably be located within these thickets regardless of external light levels.

The significant Chi-square value indicates that the vegetational types were not used with the same frequencies during periods of bright light as during periods of low light. Woodcock distribute themselves in their diurnal habitat differently under varying light conditions. Fig. 26 depicts a flushing site associated with an external light intensity of 17.5 foot-candles while Fig. 27 shows a flushing site associated

Table 14. Frequencies and percentages of flushes (according to vegetational types under periods of bright light and low light) and results of a Chi-square test comparing the two distributions.

	Bright Light*		Low Light*	
Vegetation Type	Frequency	Percent	Frequency	Percent
Heavy Timber	35	32	5	5
Switch-cane Thicket	44	40	1	1
Recently Cutover Areas	0	0	27	29
Moderately Open Timber	1	1	16	17
Blackberry & Dewberry Thicket	14	13	7	8
Total	109		93	

Results of Chi-square test comparing frequency distributions of flushes during periods of bright light and during periods of low light: X^2 cal. = 115.8; X^2 tab. = 11.07**

*Bright light was defined as any value of reflected light equal to or greater than 9.5 foot-candles. Low light was any value less than 9.5 f.c.

**Reject the hypothesis that the two distributions are the same ($p. < .05$).

Figure 26. A flushing site sampled when the external light level was 17.5 foot-candles.

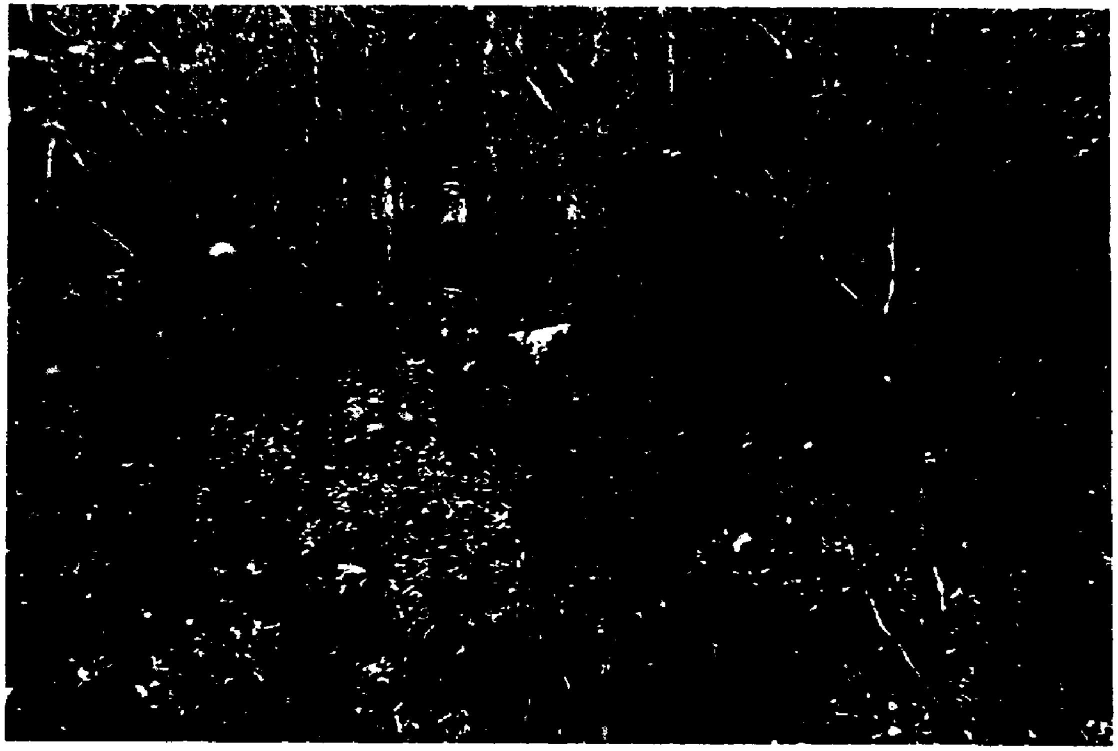


Figure 27. A flushing site sampled when the external light level was 4.1 foot-candles.

with an external light intensity of 4.1 foot-candles. The different densities of vegetation between these two flushing sites are obvious.

Findings compared to similar studies

Diurnal habitat requirements for woodcock have been the subject of research efforts for at least 40 years. A majority of this research has been conducted on the breeding range of the woodcock in the northeast United States. However, some of the observations from this area may well be applicable to the habitat data gathered in this study on the wintering grounds. Emlen (1955), in his studies of general avian habitats, and Sheldon (1967), in his work with woodcock habitat, have observed that the general structure of habitats tends to remain constant throughout the range of an avian species. A discussion of comparisons between spring, summer, and fall habitats in comparison to the observations made during the course of this study therefore seems appropriate.

1. Spring and summer habitat: -- Several investigations of singing-grounds have been conducted that illustrate the importance of a certain form or type of habitat to woodcock. Maxfield (1961), working in Massachusetts, identified certain plant indicators as being present on a majority of singing-grounds. He noted that courtship most often takes place on areas containing scattered, woody plants from 1 to 2 feet high and in early successional stages. Marshall (1958) noted that when vegetation gets to be 6 to 10 feet high, woodcock no longer use that area as a singing-ground. Blankenship (1957), working in Pennsylvania, cleared one-tenth acre plots with herbicide and found that woodcock used these treated areas extensively as singing-grounds. He concluded that early plant succession is one of the most important vegetational

characteristics of singing-grounds and that young, woody or shrubby stages of growth are the preferred floral forms for singing-grounds. The vegetational characteristics that make good singing-grounds are quite different from those identified as indicants of diurnal cover in south-central Louisiana. However, the results of these studies serve to illustrate the capability of woodcock to consistently associate themselves with a particular type of habitat. This capability was noted previously, as detailed in the section on site types and densities.

Several studies of summer habitat have been conducted that provide information relevant to the analysis of habitat in south-central Louisiana. The work of Liscinsky (1964) indicated that large, even-aged timber stands composed of one species are less useful than small, uneven-aged, mixed stands for summer habitat. He noted that the density and distribution of cover is as important as the vegetational composition and that an overstory density of about 75 percent and a ground cover density of about 25 percent are ideal for woodcock habitat. He identified alder (*Alnus* sp.) and aspen (*Populus* sp.) in immature, mixed stands as being indicative of prime woodcock habitat. He also noted greater usage was made of areas that were composed of timber stands divided into small units of varying sizes. Weeden (1955) likewise noted that woodcock were flushed more often from small, diverse patches of vegetation. These observations are analogous to several of the findings of this study. Site physiognomy and preferred light intensities were shown to be chosen in discernible patterns independent of types of plant communities, thus illustrating a need for a diversity of site physiognomy within each habitat. To provide a consistently specific light intensity at each flushing site, considering the broad range of intensities of available light, a variety of vegetative types and densities were required.

Works by Musser (1942), Pitelka (1943), Knight (1944), and Studholm, Beule, and Norris (1940) described ideal summer woodcock habitat in terms of plant communities. Although these studies indicated variations in plant communities between the areas studied, the floral forms are consistently described as thickets or swales composed of small, shrubby growths. Mendall and Aldous (1943) found that during the summer months in Maine, woodcock seek dense thickets of small, shrubby growths, which are ideally composed of immature alder saplings. His descriptions of these thickets suggest that they were similar in structure to the switch-cane thickets described in this report.

Reardon (1950) pointed out that the forest types of many areas of Maine are the result of a history of fire. He hypothesized that these fires, as well as subsequent lumbering operations, hemlock bark tanning industries, and settlement removed large portions of the forest and set back successional progression. The openings created by these activities were good woodcock habitat for the first 15 or 20 years; first as clearings that were used for courtship activities, later as cover for broods, and finally as fall flight cover. However, when these openings became too densely timbered, understory vegetation became sparse, the diversity of vegetative types was lowered, and woodcock usage diminished. His observations emphasize that young, second-growth woodland types of overstory are necessary for good woodcock habitat. This type of overstory composition was also found to be favored by woodcock in south-central Louisiana. Woodcock demonstrated a distinct preference for sites on which small-diameter, shade tolerant timber species occurred. Of particular interest is the fact that the favored overstory structure Reardon identified as being the product of a fire environment was provided on the wintering ground by groups of trees that derived their stand structure from a tolerance of shading. I found, as did Reardon (1950), that woodcock demonstrated an intolerance for open sites under a mature stand of hardwood timber.

Dunford and Owen (1973) studied the behavior of radio-equipped woodcock and found that second-growth hardwoods, alder, and hardwood-conifer mixes were the major floral forms used by woodcock during the summer months. The average tree canopy coverage of the second-growth hardwood habitat was 53 percent while the coverage of the alder coverts was 64 percent and that of the hardwood-conifer mixes was 53 percent. Ground vegetation coverage in the various habitat types averaged 44 percent. Although these values are not directly comparable to my findings due to differences in sampling techniques, the general trend indicates that the amount of ground coverage and the overstory densities observed by Dunford and Owen are lower than those I measured. One possible explanation for these differences is the variation in average external light intensity between studies during the sampling periods. The findings of the light analyses portion of this study have shown that woodcock are capable of choosing densities of habitats that are related to the quantity of available light. Although Dunford and Owen (1973) did not evaluate their data in terms of intensities of available sunlight, perhaps the average external light intensity for the periods from which their samples came was lower than the average external light intensity during the course of my study. Woodcock would have therefore been found in less dense cover.

Some of the most extensive work on diurnal summer habitat has been done by Sheldon (1967). He concluded that vegetative requirements are diverse and that an ideal habitat should have floral forms ranging from a few inches high to trees taller than 30 feet. He pointed out that alder (in stands less than 20 years of age) is one of the best indicators of diurnal habitat on the breeding range of woodcock. Forestry practices that he found to be beneficial for creating woodcock habitat are clear-cutting and controlled burning. He concluded that timber stands, which have no crown closure, allow understory plants to grow too thick for ideal woodcock habitat. In areas such as this he recommended allowing cattle to graze on the understory until an attractive density is obtained. The control of understory density, which he recommended achieving by clear-cutting, burning, or grazing, occurred naturally on the areas used in my study due to the timber stand composition. Heavy understory densities occurred in natural openings of the overstory, while lesser understory densities were provided by areas of heavier overstory density. Those forestry management techniques recommended for providing optimum cover on the summer range of woodcock are inappropriate for habitat on the winter range. Clear-cutting of bottomland hardwood areas, such as those described in this study, would result in such a proliferation of herbaceous and shrubby growth that no habitat diversity would be provided. Prescribed burning in these areas would remove the shade tolerant tree species as well as canebrakes, blowdowns, and other habitat types found to be important diurnal cover. Also, fire would permanently damage the larger and more commercially important overstory tree species. Cattle grazing, however, could be used as a regulator of cover density, particularly in habitats with very dense, homogenous areas of understory growth.

2. Fall habitat: -- Although the literature does not indicate any substantial difference between the preferred summer and fall habitats, some atypical choices of cover have been noted during the fall months. Thompson (1965) found eight woodcock in a marsh composed of chest-high bulrush in New York during late September. This habitat was not composed of plant species considered to be "typical" woodcock habitat and therefore probably was chosen on the basis of structure. The physiognomy and light reduction capabilities of a bulrush marsh are quite similar to those of the canebrakes discussed in this report. Thompson's observations suggest that habitat structure is more important than plant species composition.

Sheldon (1967) observed that woodcock concentrate at dusk on certain areas and depart at dawn for resting places during the fall just as during other times of the year, thereby suggesting that light, rather than a cue provided by resident habitat, may be responsible for movements and subsequent habitat selection.

Mendall and Aldous (1943) found that during September and October in Maine, 45 percent of woodcock flushes occurred in alder thickets, 35 percent in second growth hardwoods and 17 percent in timber stands of mixed species. However, as fall advanced, a higher priority (63 percent) was placed on alder thickets. The increased usage of alder with the progression of fall may be associated with the leaf fall of the deciduous tree species. A loss of leaves would decrease the density of the overall habitat so that optimum light intensities would be found in areas of dense vegetation such as thickets. Alder, particularly during its first 20 years, is found in even-aged stands of high stem density that would be capable of forming this thicket-type structure (Sheldon 1967). A shift in habitat preference with seasonal changes was not observed on the wintering grounds, possibly because most deciduous trees had lost their leaves by the time wintering woodoock arrived. Because deciduous trees were incapable of substantially reducing light intensities during winter months, trends of habitat usage may have been more easily detected. That is, there were only a few types of diurnal habitat such as canebrakes or blackberry and dewberry thickets that provided dense habitats. Had the deciduous tree species been fully leafed, more uniformity of habitat density would have been observed.

3. Winter habitat: -- Woodcock winter in two distinct types of habitat in Louisiana (Glasgow 1958). They are found in the southwest and north-central areas of Louisiana, which are composed of mixed forests (conifers and hardwoods), and in the southeast portion of the state, which is primarily an area of bottomland hardwood forests. Although these two areas vary considerably as to general plant speciation, the vegetational types reported to be important habitat constituents are quite similar for both areas (Reid and Goodrum 1956).

Britt (1971), working in the bottomland hardwood forests of southeast Louisiana, found that on three separate study sites, all life forms of vegetation composing diurnal habitat were virtually identical regardless of species composition. He found that during the day woodcock were usually found in the densest cover available. He divided his study areas into three general categories of vegetation; understory, midstory, and overstory. He found that the overstory vegetation did not significantly contribute to the choice of a particular habitat by woodcock;

except that it might act to prevent extremely thick understory growth, thereby excluding woodcock usage. He described the ideal midstory habitat as being "picket fence-like" in appearance with erect and spreading floral forms. The importance he recognized for this vegetational layer was its vertical distribution. He found the ideal understory to be composed of decumbent and canopy-like thickets or swales. The importance of this vegetational layer was its horizontal distribution. Ideal cover comprised less than 18 percent of the total area of his study sites. Although he dealt only briefly with site physiognomy, Britt's overall observations on ideal cover are virtually identical to those of my study. However, he did not analyze his habitat data on the basis of external light so that any changes of habitat preference in response to changing light conditions would not be detected.

Both Glasgow (1958) and Britt (1971) mentioned the importance of proper cover density to winter habitat. The ideal cover density was described by both authors as one capable of reducing a substantial amount of sunlight. The findings of this study agree with these observations and hopefully provide more definitive information on the subject.

Summation of Site Factors

Certain vegetational types and certain overstory types and sizes were identified as being important constituents of diurnal habitat for woodcock. Important vegetative types recognized by this study included blackberry and dewberry thickets, switch-cane thickets, rattan-vine, cross-vine, and reproduction of tolerant tree species. The overstory trees associated with woodcock flushes were tolerant species of a small diameter, prone to epicormic branching, and growing in dense stands.

Those plant species that were indicative of good woodcock habitat regularly occurred in physiognomic groups or types that are best described as thickets or swales. Open, sparsely vegetated types were selected against by woodcock. Site density data showed the preferred vegetative types to be significantly denser than the random or typical vegetative types encountered on the study areas. However, an analysis of these vegetative types under varying light conditions showed that the preferred density changed in response to the amount of available sunlight. In all habitats analyzed, woodcock showed an affinity for a very narrow range of light intensity. Regardless of the amount of available sunlight, woodcock chose sites that had approximately 4.5 foot-candles of reflected illumination. A diversity of vegetation densities was necessary if an area was to provide the optimum light intensity under different external light conditions. The average light reduction for all diurnal flushing sites under all intensities of sunlight was approximately 70 percent. The data presented in previous works, although not expressed in the same units of measure, generally follows these findings.

Eye Analyses

Investigations of diurnal habitat showed that woodcock are capable of choosing cover on the basis of site structure and resultant light intensity. This ability to choose cover implies a preference for a particular light intensity, which in turn implies that woodcock have the ability to perceive differences of illumination. If indeed light intensity was a principal cue in woodcock habitat selection, then a morphological analysis of the woodcock eye might identify a physiological basis for this preference of a specific light intensity.

External Features

One of the most striking features of the woodcock eye is its relatively large size. Fig. 28 contrasts woodcock eyes with those of a Bobwhite of comparable size and weight. The woodcock eyes are approximately 50 percent larger. Waterman (1971) has observed that eyeball size is related to the size of the projected image and is an adaptation to the light gathering demands of the animal. Nocturnally oriented animals usually have large eyes so that they can gather more light during periods of reduced illumination.

Most nocturnally oriented birds have evolved an elongated or "tube shaped" eyeball (Pumphrey 1961). Waterman (1971) has observed that the tubular eye is a modification for meeting the demands of a large eye in a small skull. The tubular shape is accomplished by constricting the eye at the junction of the cornea and the receptor section. The cartilagenous ring around the eye at this junction is made up of scleral ossicles. Fig. 28 shows the woodcock eye to have no cartilagenous ring nor a tubular shape. Instead, the eye is ovoid shaped and flattened at the anterior end. Waterman (1971) and Pumphrey (1961) have observed that this eye shape is characteristic of diurnally active birds.

To accomodate these large eyes without the structural benefits of a tubular shape, woodcock have undergone a modification of the brain. Cobb (1959) has observed that the woodcock eye achieved its large size and posterior location via a positioning of the brain rearward and downward to the point where it is sometimes referred to as an upside-down brain.

Speculations as to why the woodcock evolved a large eye, which is considered to be an attribute for nocturnal activity, yet maintained the

Figure 28. A comparison of the size of the eyes of a Bobwhite to an American Woodcock.

ovoid shape characteristic of diurnally active birds, are interesting. Pumphrey (1961) has pointed out that the advantages of the ovoid shape, as opposed to the tubular shape, are the structural support it provides and its capability for allowing movement of the eyeball in the socket. In avian species with tubular shaped eyes, no movement of the eyeball in the socket is possible and the structural support is provided by the ring of scleral ossicles forming the medial constriction. There is no reason to assume that woodcock, like other avian species with large eyes, would not have evolved tubular shaped eyes if there was not an advantage to retaining the ovoid shape.

The relative value of maintaining the ovoid eye shape and the posterior location of the eye is emphasized by the alteration of the brain position. Both of these characteristics indicate that woodcock are capable of eye movement and that there are several advantages provided by this capability. Pumphrey (1961) has pointed out that in most birds, the eyeballs are almost in contact in the mid-line so that eye movements are reduced to a very small compass. Woodcock, however, have eyes spaced widely apart and posteriorly located so that they are relatively far apart at the mid-line. If any frontal, binocular vision is possible, this vision would have to be facilitated by a movement of the eyeball. Species of birds with tubular shaped eyeballs, such as owls, are incapable of any eyeball movement and they must compensate for this by moving the head and neck. Other birds, however, have the capability of forward convergence toward the tip of the bill by using the extraocular muscles. Although these muscles are very weak in all birds, they are at least capable of functioning if the eyeball can rotate in its socket. The main advantage of the ovoid eye shape to woodcock is probably the movement it permits. The ability to focus attention at the tip of the bill would have definite advantages to surface feeding. Sheldon (1967) has observed woodcock feeding rapidly on ants and chasing flying moths. Glasgow (1958) reported that during wet periods, woodcock often feed on worms that have come to the surface.

A summary of the external features of the woodcock eye indicates that this organ is highly specialized to accomodate a variety of needs. The size of the eye makes it an efficient gatherer of light and allows the woodcock to function during periods of low light intensity. The posterior position of the eye enables the woodcock to see above and behind when feeding and keeps mud and debris from getting in the eye when probing (Cobb 1959). The shape of the eyeball suggests that the woodcock is capable of eye movement. On several occasions, eyeball movement was noted in woodcock as they were removed from cloth bags in which they were held prior to banding. This movement was observed most frequently when they were removed from the bag upside down and then turned over. Although these woodcock were undoubtedly disoriented, these observations serve to demonstrate that woodcock have the capability of eye movement. During nocturnal banding operations, I noted that when a spotlight was placed on a woodcock and the eye shine was observed, the intensity of the shine would often change. This change of intensity occurred without any perceptible change in position of the body or the head. Several banders who had made the same observations were interviewed. Possibly this change of eye shine intensity was a chemical reaction of the eye to the light, but the possibility exists that this change was caused by a movement of the eyeball to avoid the direct beam of the light.

Internal Features

To obtain more definitive information about any possible physiological basis for habitat preferences, a comparison was made of the internal eye morphology of woodcock with that of two other bird species. These were the Bobwhite, a diurnally active ground dweller, and the Chuck-will's-widow, a nocturnally active species.

Walls (1942) observed that crepuscular or nocturnal animals have an enlarged cornea. A comparison of the woodcock eye to that of the other two species showed that the proportionate cornea size of the woodcock eye was comparible to that of the Chuck-will's-widow and much larger than that of the Bobwhite. Waterman (1971) points out that the cornea is the site of light entry and refraction, and this comparison suggests that the woodcock eye is an efficient light gatherer.

Although the capacity of an avian eye to absorb light is primarily controlled by the size of the cornea, the ability of the eye to function under various light intensities is dependent on the structure of the retina. As Waterman (1971) observed, "Eyes have evolved to gather and focus light upon the photoreceptive membrane, the retina." To test for differences in functional response to varying light intensities, a comparison of retina structure was made. Sections were removed from the retina of each of the three species of birds, stained, and photographed at a magnification of 100X. Care was taken to avoid including any portion of the foveae in these samples because this would have distorted the measurements of width of the various tissue layers. The width of each tissue layer was measured at five points, averaged, and then recorded as percent of total width.

Except for an inexplicably narrow optic nerve layer in the Chuck-will's-widow, all tissue layers were of comparable size down to the layer of rods and cones (Figs. 29, 30, and 31). The layer of rods and cones in the retinae of the Chuck-will's-widow and the woodcock were of comparable proportion. These proportions are about twice that of the Bobwhite (Table 15). A comparison of the composition of this tissue layer shows that the Chuck-will's-widow has a preponderance of rods while the Bobwhite eye has a preponderance of cones. The woodcock eye represents an intermediate situation, in that the ratio of rod density to cone density seems to approximate unity. Waterman, (1971) discussing functions of the retina, noted that rods have a low threshold to light stimulation and are effective in dim light (twilight vision). On the other hand, cones have a high threshold to light stimulation and require good illumination to be properly stimulated. Pumphrey (1961) noted that visual receptor cells of owls are almost exclusively rods and that their terminal segments are very long. This elongation results in less light being wasted in the pigment layers and sclera. Based on the density of rods, the woodcock eye is not as effective at twilight vision as that of the Chuck-will's-widow; however it is certainly more functional under low light intensities than the eye of the Bobwhite. Also, there is evidence that the woodcock eye is more efficient under low illumination than the rod density observations indicate. An examination of the rods in the woodcock eye shows an elogation of the terminal end. The fact that the rod and cone layer in the woodcock eye was proportionately wider than either of the other two types substantiates this observation. Because this elongation is designed to reduce the loss of absorbed light, it must be an advantage for nocturnal vision.

Figure 29. A section of the retina of the American Woodcock photographed at 100X magnification.

Figure 30. A section of the retina of the Bobwhite photographed at 100X magnification.

Figure 31. A section of the retina of the Chuck-will's-widow photographed at 100X magnification.

Table 15. Comparisons of the composition of the retinae of three avian species.

	American Woodcock		Bobwhite		Chuck-will's-widow	
Tissue Layer	thickness (millimeters)	% of total thickness	thickness (millimeters)	% of total thickness	thickness (millimeters)	% of total thickness
Optic nerve layer	.1693	23%	.1566	24%	.0593	11%
Ganglion cell layer	.0169	2	.0381	6	.0212	3
Inner plexiform layer	.1354	18	.1524	25	.1778	32
Inner nuclear layer	.1482	20	.1778	27	.1354	24
Nuclei of rods and cones	.0847	12	.0550	8	.0593	11
Rods and cones	.1778	25	.0677	10	.1016	19
Total	.7323		.6476		.5546	

From the internal comparisons outlined, I concluded that the woodcock eye is designed to accomodate a variety of functions. The light gathering capacity provided by the large cornea, and the efficiency for retaining absorbed light provided by the elongated rods, are distinct advantages for nocturnal vision. On the other hand, the cone density is high enough to suggest that woodcock are capable of adequate vision during the daylight hours.

Food Habits

Samples of amounts and types of woodcock foods were analyzed from 677 woodcock stomachs collected between 1970 and 1974. Collection intervals of one hour were established and collections were made from each of the 24 one-hour periods. Stomach contents were compared to the food items extracted from soil samples taken at each flushing point. The contents of these soil samples were then compared to the contents of the random plot samples.

Amounts of Foods

The amount of the foods eaten was determined by volumetric analysis of woodcock stomachs collected from diurnal and nocturnal habitats. Each stomach sample was assigned a numerical value describing the digestive stage to supplement information from stomach volumes.

Although the collection times were recorded in minutes after sunrise, for illustrative purposes these were converted to hours after sunrise. The stomach volumes for each hourly period were averaged and standard errors were computed for the means. The close adherence of the confidence limits to the mean shows that there is a pattern to the temporal variations of stomach volume and that this pattern displays consistent variation (Fig. 32). These patterns show cyclic feeding intervals that are easily recognized as: early morning (0100-0500 hours), midday (1000-1300 hours), and sunset (1700-2100 hours).

The mean digestive stage values for each hourly period are illustrated graphically in Fig. 33. This graph illustrates that stomach contents were relatively undigested in early morning, mid-morning, and early evening. These periods of early digestion stages correspond very closely with the peaks of feeding activity illustrated in Fig. 32, thereby supporting the observations concerning cyclic feeding.

Because not all hourly intervals were sampled with the same intensity, a Least Squares Analysis of Variance for disproportionate data levels was conducted to test for relationships of time and digestive stage to stomach volume. The results of this Analysis of Variance are presented in Table 16. In this table, stomach volume is the dependent variable and when analyzed with the independent variable "Time," an F value of 4.843 was obtained. This value suggests that digestive stage varies with stomach volume in a non-random manner. When compared with "Time x Stage," an F value of 1.928 was obtained. This value is also significant and illustrates that the relationship between digestive stage and stomach volume was not the same for all times of the day. This table shows that these three factors are not independent of one another and are related at a significant statistical level.

The findings of these analyses point out two important aspects of the feeding behavior of woodcock. First, the feeding frequency and volume information were indicative of the amounts of food needed daily

Figure 32. Mean stomach volumes of woodcock collected at hourly intervals.

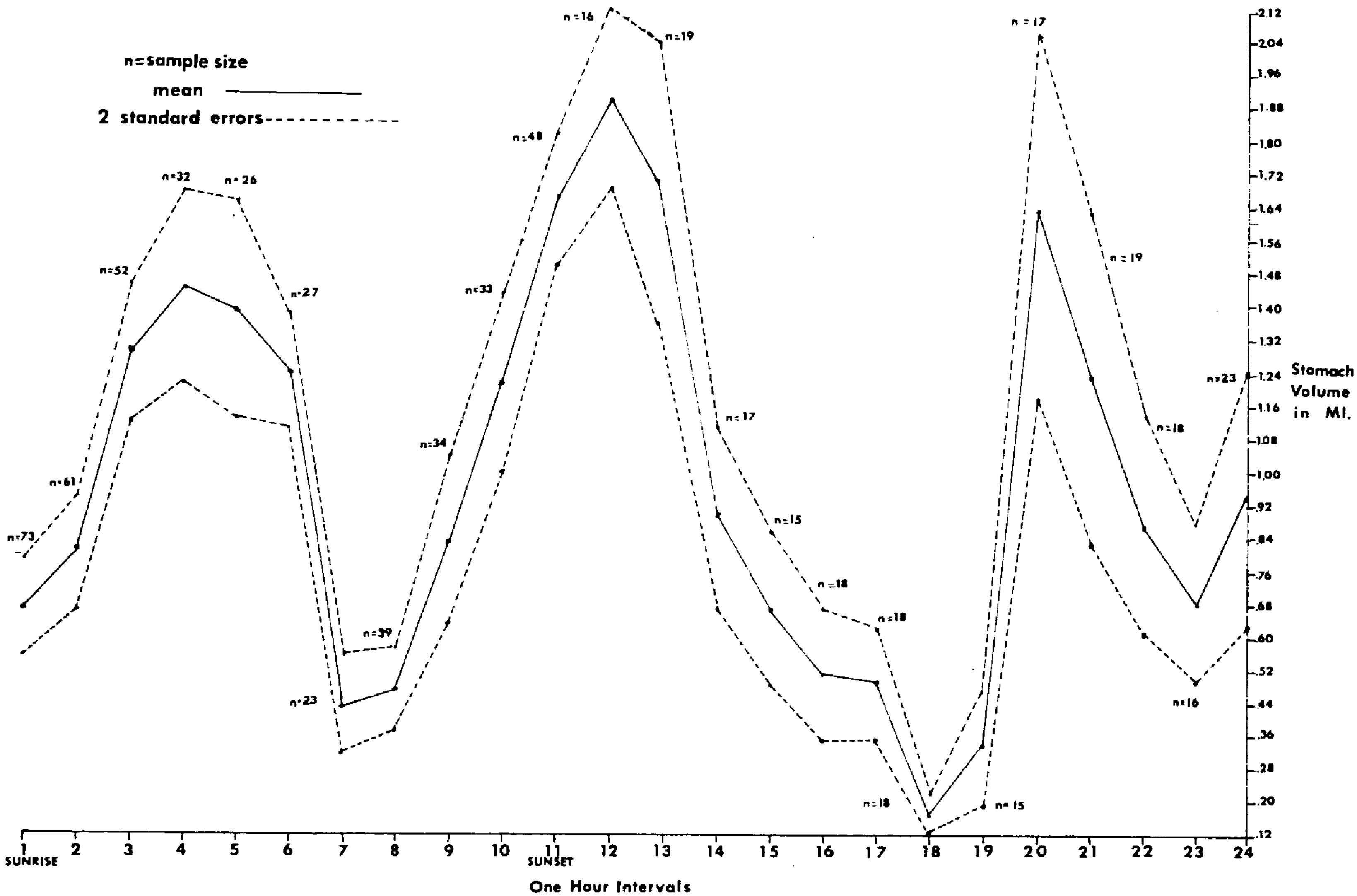
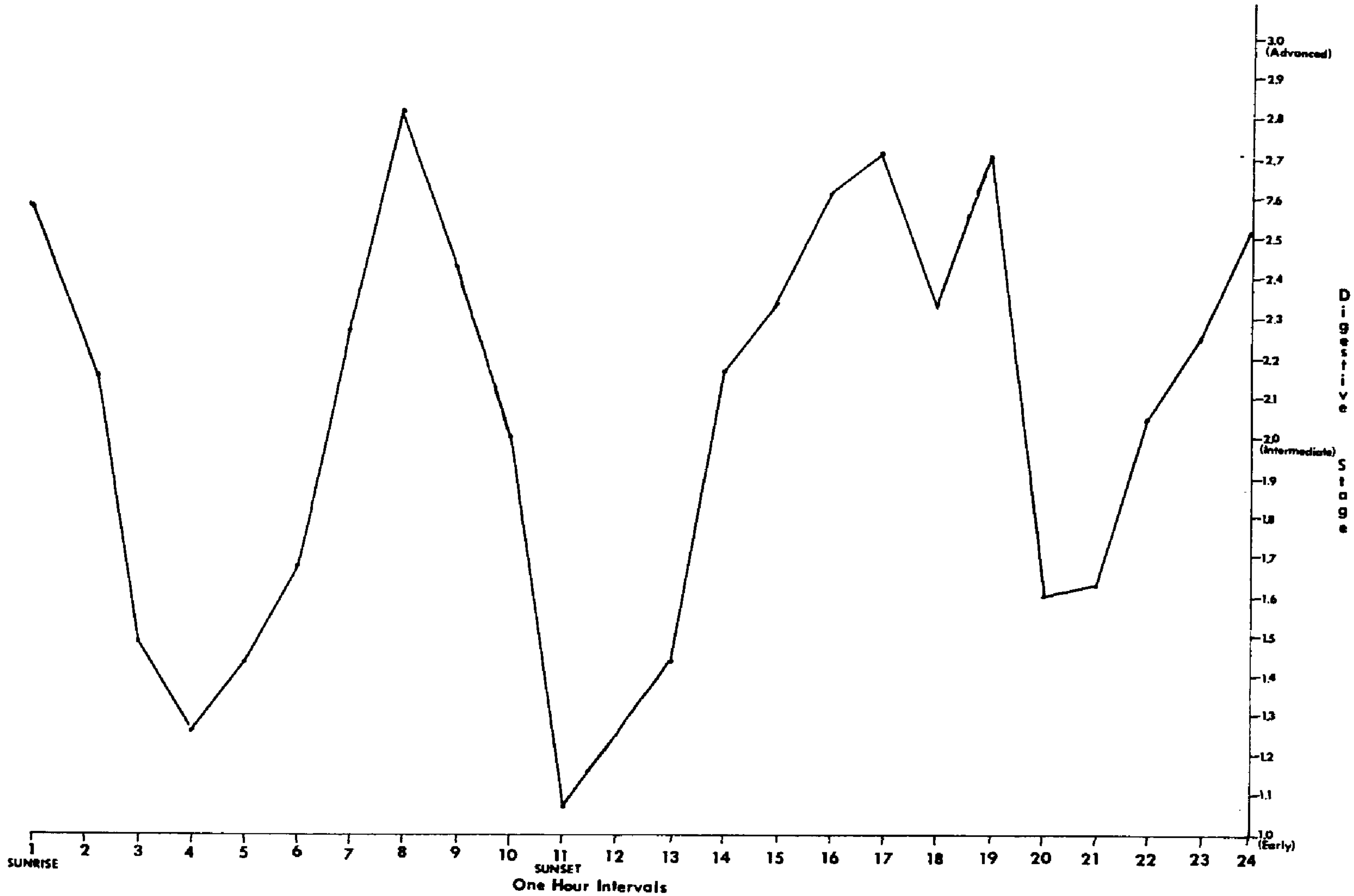

n=sample size
mean
2 standard errors
n=73
n=61
n=52
n=32
n=26
n=27
n=23
n=39
n=34
n=33
n=48
n=16
n=19
n=17
n=15
n=18
n=18
n=18
n=15
n=17
n=19
n=18
n=16
n=23
Stomach Volume in Ml.
2.12
2.04
1.96
1.88
1.80
1.72
1.64
1.56
1.48
1.40
1.32
1.24
1.16
1.08
1.00
.92
.84
.76
.68
.60
.52
.44
.36
.28
.20
.12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SUNRISE
SUNSET
One Hour Intervals

Table 16. Least squares analysis of variance to test the effect of time of collection and digestive stage on stomach volume.

Source	Degrees of Freedom	Sum of Squares	Mean Squares	$F_{Cal.}$	$F_{Tab.(0.05)}$
Total	677	333.404			
Total Reduction	68	181.710	2.6722	10.710	
Mu-YM	1	8.629	.6295	2.523	
Time	23	27.792	1.208	4.843	1.56
Digestive Stage	2	23.295	11.647	46.683	3.00
Time x Stage	42	20.203	.481	1.928	1.41
Remainder	609	151.694	.249		

Figure 33. Mean digestive stages of woodcock stomachs collected at hourly intervals.


3.0
(Advanced)
2.9
2.8
2.7
7.6
2.5
2.4
2.3
2.2
2.1
2.0
(Intermediate)
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
(Early)
Digestive Stage
1
SUNRISE
2
3
4
5
6
7
8
9
10
11
SUNSET
12
13
14
15
16
17
18
19
20
21
22
23
24
One Hour Intervals

by woodcock. Secondly, there were three definite feeding cycles with peaks twice during the day and once at night.

Previous studies pertinent to feeding intervals

More work has been done on the nocturnal feeding habits of woodcock than on the diurnal feeding habits, probably because of the greater ease with which woodcock may be collected at night. Not all of the literature, however, agrees as to the frequency and type of nocturnal feeding. Sheldon (1961) has stated that the reason for nocturnal flights seems to be dietary in nature. He has observed woodcock feeding at dusk in open fields. Previous workers (Pettingill, 1936 and Mendall and Aldous, 1943) have also reported woodcock feeding at night in the northeastern United States. Martin (1962) and Kletzly and Rieffenberger (1967) have noted nocturnal usage of openings by woodcock during the summer months and indicated that this usage was associated with feeding activities. Other workers have questioned the hypothesis that the occupancy of open fields at night is strictly for feeding purposes. Dunford and Owen (1973) pointed out that explanations as to why woodcock use open fields at night during the summer months in Maine are only speculative. They suggest that open fields may provide the greatest safety from predators and may primarily be used as roosting sites. They studied nocturnal behavior by means of radio telemetry and ascertained that nocturnal activity was minimal and that woodcock feed very little at night. Weeden (1953), working in Maine, observed that most nocturnal feeding occurs in areas other than open fields during the breeding season. He suggested that there might be "accessory feeding" areas that are used during the breeding season. Krohn (1970) concluded that in Maine open fields were not used during the summer months for feeding activities. He collected woodcock before and after they alighted in open fields at night and compared the stomach contents for the two periods. He found that woodcock fed prior to entering fields at night and that little feeding activity occurred once they entered these fields. Sheldon (1967) observed that captive woodcock fed three times during a 24 hour period; at dawn or just before, at noon, and just prior to sunset. He noted that during the midday interval, more food was consumed than during the other two periods. He also noted that when one or more woodcock began to feed, other woodcock began to feed.

Almost all of the information available about the food habits of woodcock on their winter range comes from the works of Glasgow (1953, 1956, 1958). He felt that the main purpose of the large aggregations of birds in open fields at night in Louisiana was dietary. He observed that woodcock flew into these large open fields about one-half hour after sunset and postulated that they fed from twilight until approximately 11:00 pm. After 11:00 pm they were observed resting and this continued until just before daylight when he believed that they resumed feeding. They typically exited the fields a few minutes after dawn. He also observed that woodcock did not always remain in these fields overnight. On bright nights, birds were observed flying into fields and then almost immediately departing presumably to timbered areas. This behavior would suggest that these birds may have fed in timbered areas during the night. Glasgow also commented on the conditions of the nocturnally-used fields. He found that woodcock did not randomly distribute themselves over the expanse of a field, but rather concentrated in those areas that were moist and contained cover from 1 to 6 feet high interspersed with small, open areas. He felt that these areas in the fields were chosen as much for the cover they provided as for the abundance of earthworms. Ensminger (1954) worked in the same general area as Glasgow and found that earthworms were equally abundant in fields where there were no woodcock and that cover was probably more important for dictating preferences for certain fields or areas within fields. He was impressed by the lack of evidence of probing in fields where woodcock were numerous. Britt (1971) found that the largest volume of animal material in woodcock stomachs collected in southeast Louisiana occurred within one hour after sunset. He also found that stomachs collected from midnight to 4:00 am contained small amounts of animal material and those collected from 4:00 am to dawn contained almost no animal material.

The diurnal feeding habits of woodcock have received considerably less study than have nocturnal feeding habits. Some of the early works on woodcock feeding habits indicated that diurnal feeding occurred only during periods of climatic stress. However, Mendall and Aldous (1943) observed woodcock in Maine feeding along a small creek during mid-morning in April. They noted that at one time or another all of the birds they observed were engaged in feeding activity. Sheldon (1967) observed woodcock feeding on surface insects during the day. He reported shooting two woodcock that had earthworms in their bills during mid-morning. Weeden (1953) indicated that shifts in dirunal habitat by woodcock are brought about by changes in feeding conditions. Miller (1957) analyzed the contents of woodcock stomachs and compared the volumes to time of day. He concluded that since large amounts of animal material were present in the stomachs collected in the afternoon that heavy feeding must have occurred prior to this period.

On the wintering range of woodcock very little research has been conducted on diurnal feeding behavior. A report of a woodcock feeding in mid-afternoon in southeast Texas was provided by Glasgow (1958). During extremes of climatic conditions, several observations of woodcock feeding during daylight hours in extreme southern Louisiana have been documented (McIlhenny 1940) (Murry, R. E., Louisiana State University, Baton Rouge, La., per. comm.). Britt (1971) observed relatively low volumes of material in stomachs collected in diurnal habitat in southeast Louisiana. However, his samples included only two stomachs that were collected prior to 2:00 pm. His data showed significantly higher stomach volumes for woodcock collected one hour after sunset than for any other time. He felt that a majority of this food was eaten after woodcock arrived in the nocturnal-use fields, however, he suggested that some of this feeding may have occurred in diurnal cover prior to the arrival in the nocturnal-use fields.

<u>Conclusions regarding amounts and frequency of feeding</u>

The consumption values presented by several authors emphasize that woodcock must eat a substantial quantity of food daily. The high consumption rates reported for captive woodcock by Sheldon (1967) were probably due to the fact that they were fed only earthworms, that have a higher bulk to protein ratio than do other food items. Assuming the same approximate metabolic requirements for wild woodcock as those determined for captive woodcock, there evidently must be a high rate of energy provided regularly. This observation was substantiated by the volumetric analysis of this study that clearly identified three distinct feeding periods.

Although Sheldon (1967) observed a cyclic feeding phenomenon in captive woodcock, other authors, working with wild woodcock, have been unable to detect this type of feeding regularity. Considering the procedures used in other studies, sample sizes may have been inadequate to identify all feeding intervals. Almost all workers have recognized a feeding period immediately before sunset. My study identified an influx of feeding activity immediately prior to the nocturnal entrance into open fields. Most authors agree that some feeding occurs during the night and several workers have found a substantial amount of feeding activity during the day. While there is a valid argument that feeding behavior must surely change between summer and winter ranges, between time of the year, or between habitat types, the findings of this report are very similar to the cumulative findings of other food habits workers with respect to feeding periodicity. In all likelihood my study had a sampling procedure intense enough to identify these intervals whereas other workers have only witnessed portions of the total temporal feeding fluctuations.

Types of Foods

The types of foods eaten by woodcock were determined by washing all material from the esophagus, proventriculis, and ventriculis then recording the recognizable material. Identification of partially digested material was often difficult.

Eleven types of animal material were extracted from the 677 woodcock stomachs during the course of this study. These types, as well as the data for the unrecognizable material, were graphed as to frequency of occurrence by each hourly interval and these are presented in

Figs. 34 through 45. These graphs represent the percent of woodcock that consumed certain food items rather than the amount of each species that was consumed. Of the 11 categories of food items, the samples were so small for the soldierfly larvae and horsefly larvae that the results of the analyses for these two types are of limited value. There were four types (millipedes, cranefly larva, white grubs, and the unknown category) that showed oscillations of frequencies comparable to the oscillations observed for the volume data (Fig. 32).

Three food types did not show the same magnitude of oscillations as the previously discussed types; however, the oscillations that did occur were at the same times as the other food items. These food types were the earthworms, ground beetles, and snails. The earthworms and ground beetles frequently occurred during all periods of day and night and were obviously preferred food items. The low magnitude of the oscillations, combined with the high frequency of occurrence for these two types, indicates that they were probably eaten whenever they were encountered; although they were more actively pursued during the three feeding periods.

Three food types were fed upon extensively at night and very little during the day. These were spiders, lepidoptera larvae, and fire ants. All three of these types occurred most frequently in samples collected within two hours after sunset. This period corresponds with the evening feeding interval identified in the volumetric analysis.

Fire ants, ground beetles (Carabidae), earthworms, and millipedes occurred more frequently in woodcock stomachs than any of the other food items. The mean number per stomach of these four types for each hourly interval are depicted graphically in Fig. 46. The consumption of

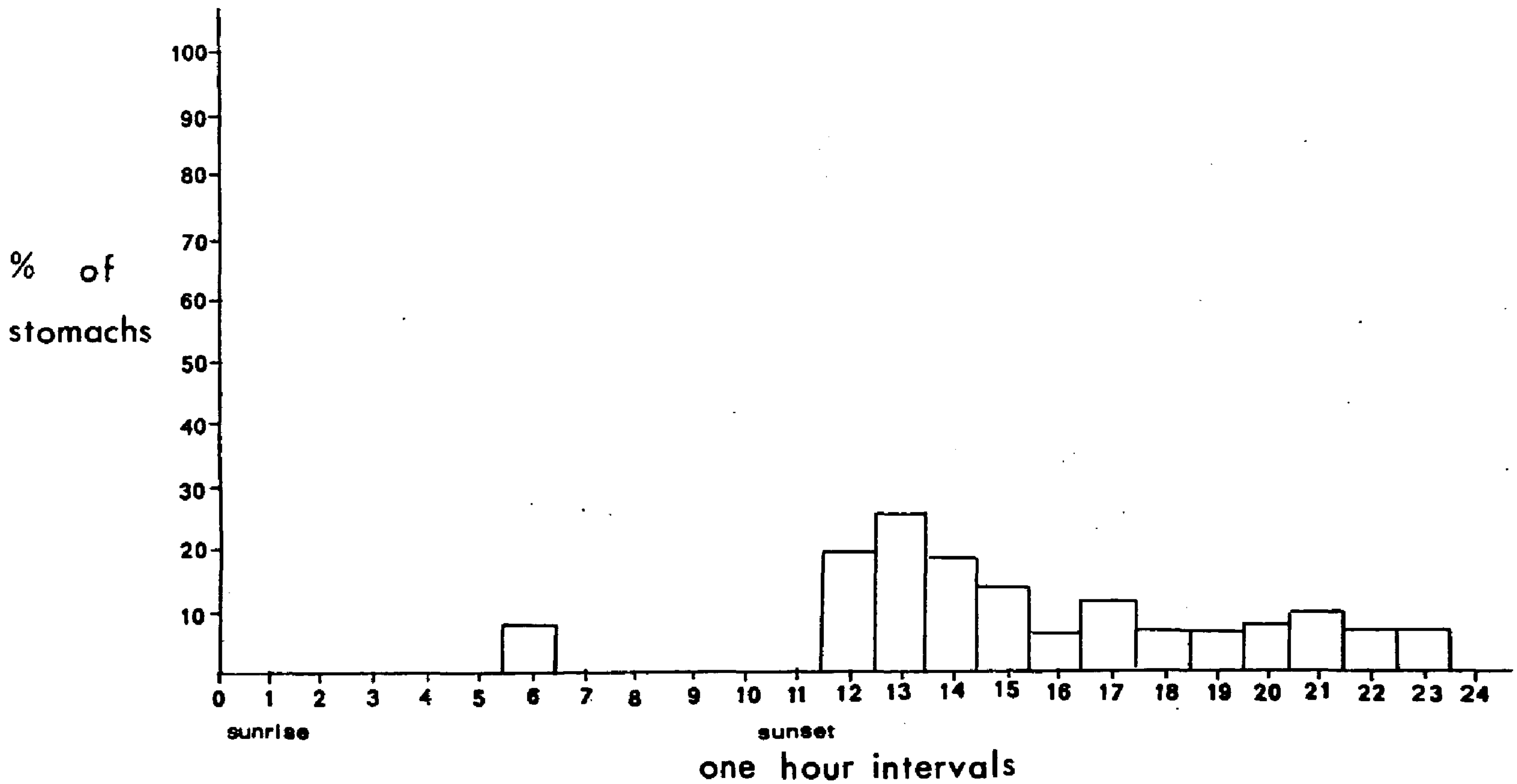


Fig. 34. Percentage frequency of spiders (Araneida) in woodcock stomachs at hourly intervals.

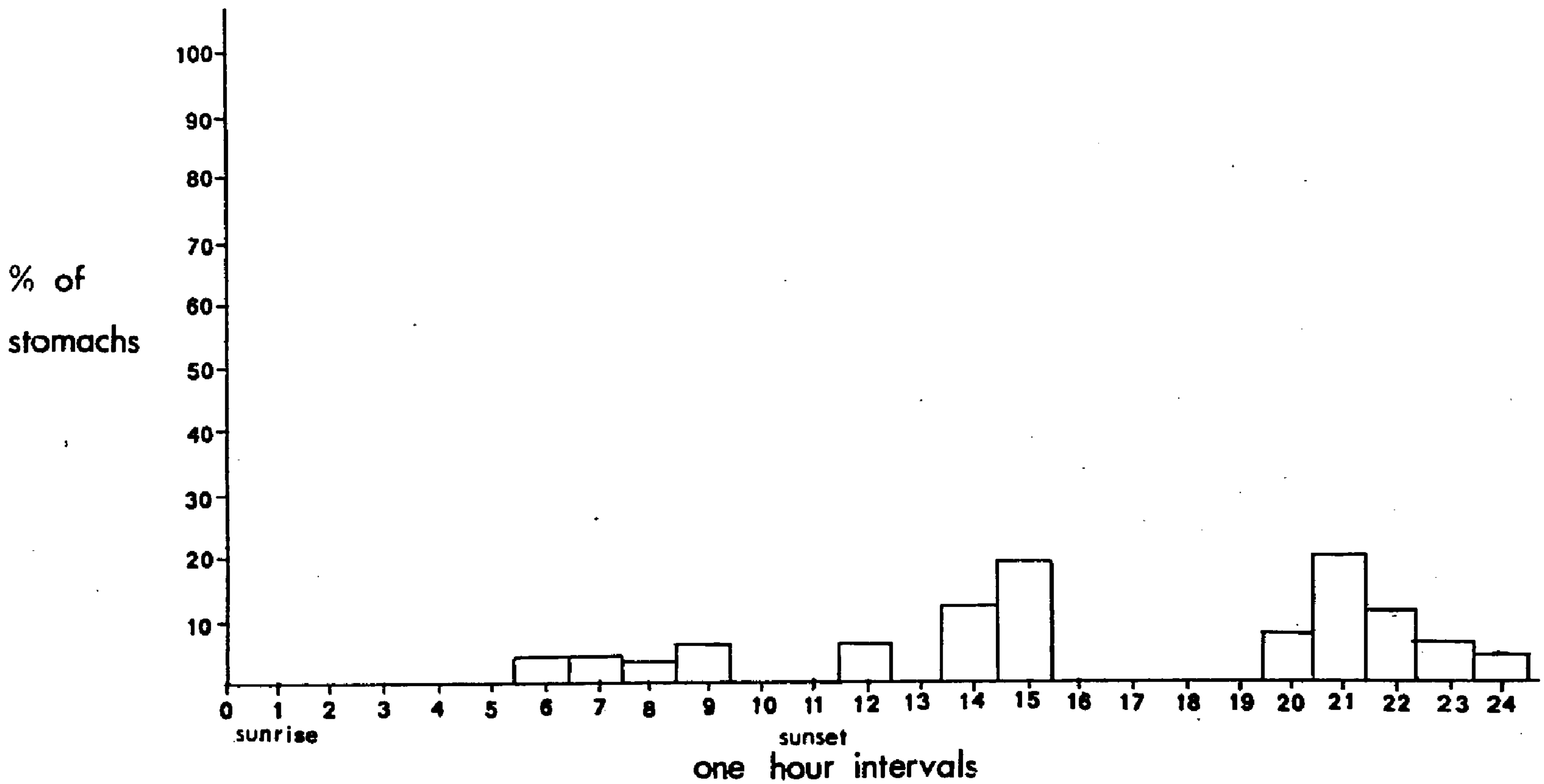


Fig. 35. Percentage frequency of soldierfly larvae (Stratiomyidae) in woodcock stomachs at hourly intervals.

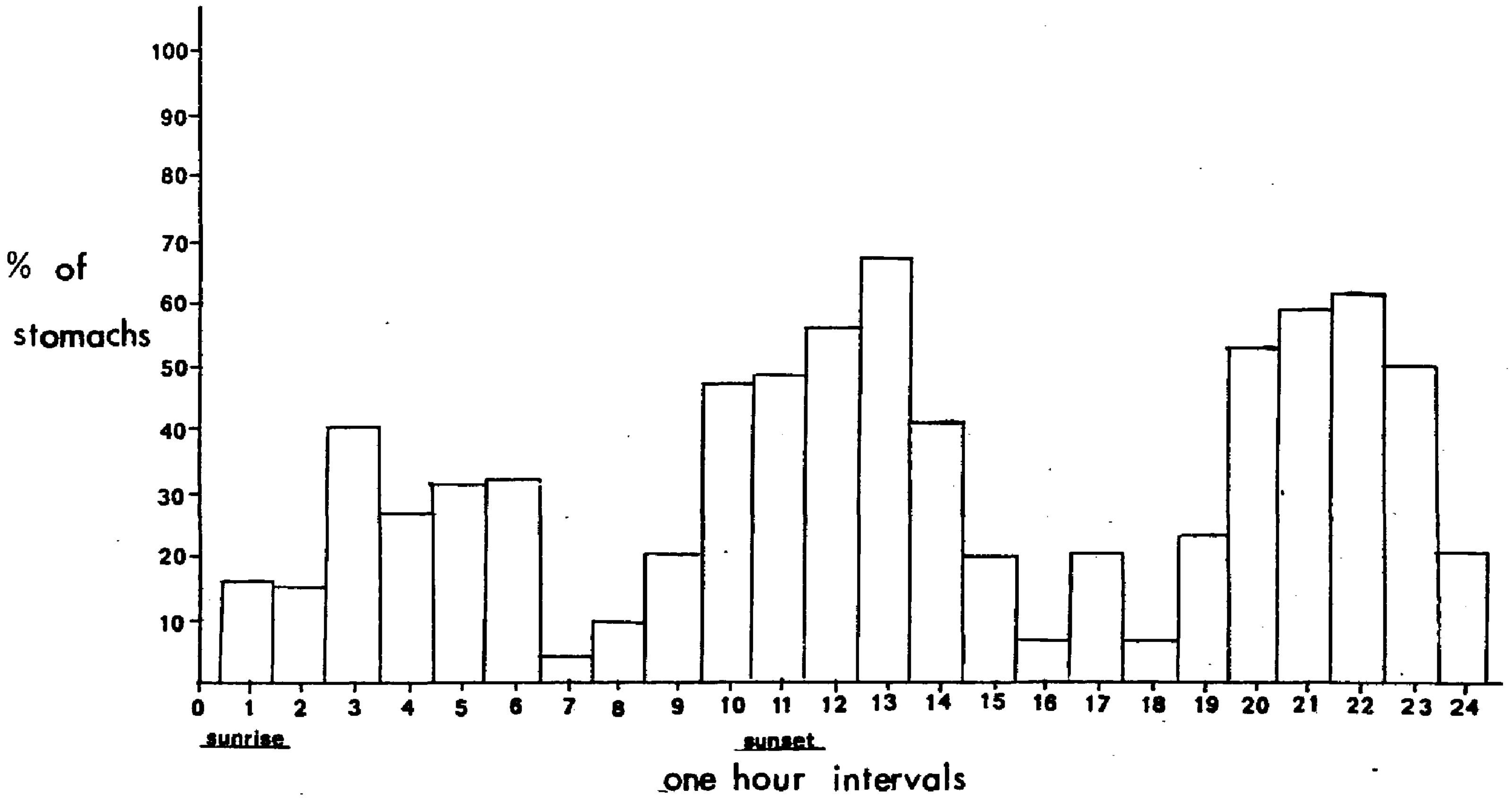


Fig. 36. Percentage frequency of cranefly larvae (Tipulidae) in woodcock stomachs at hourly intervals.

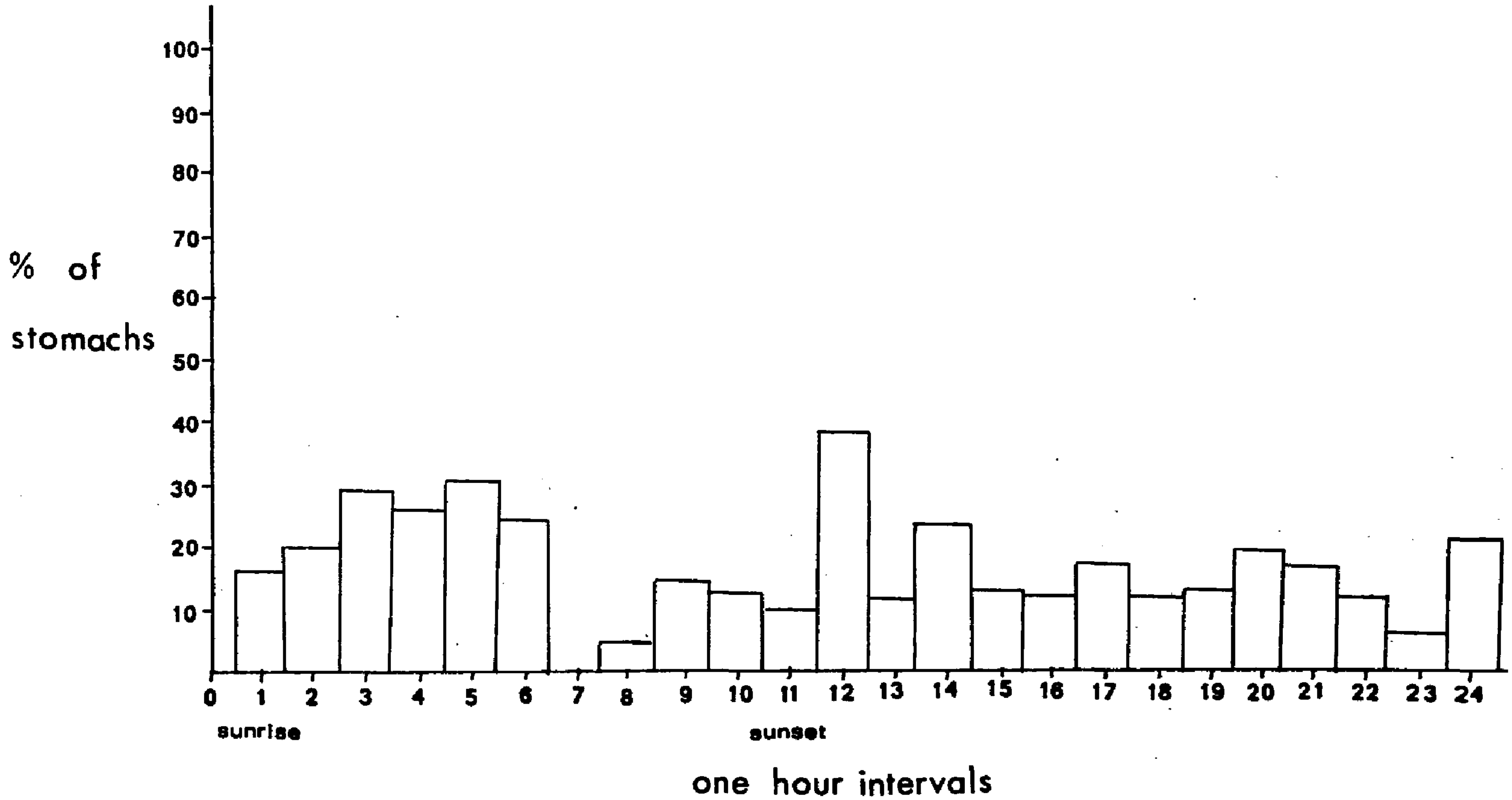


Fig. 37. Percentage frequency of snails (Gastropoda) in woodcock stomachs at hourly intervals.

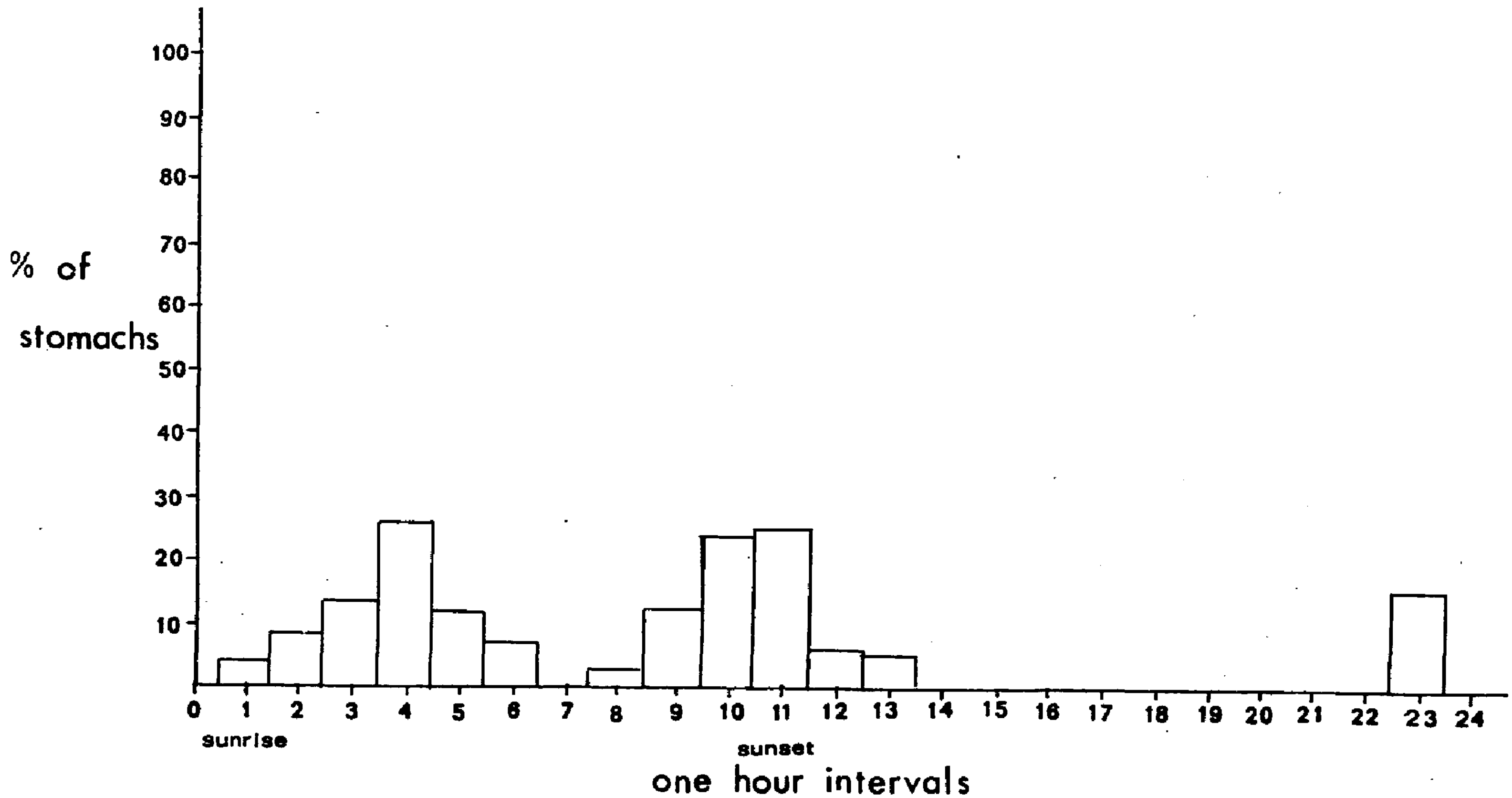


Fig. 38. Percentage frequency of white grubs (Phyllophaga sp.) in woodcock stomachs at hourly intervals.

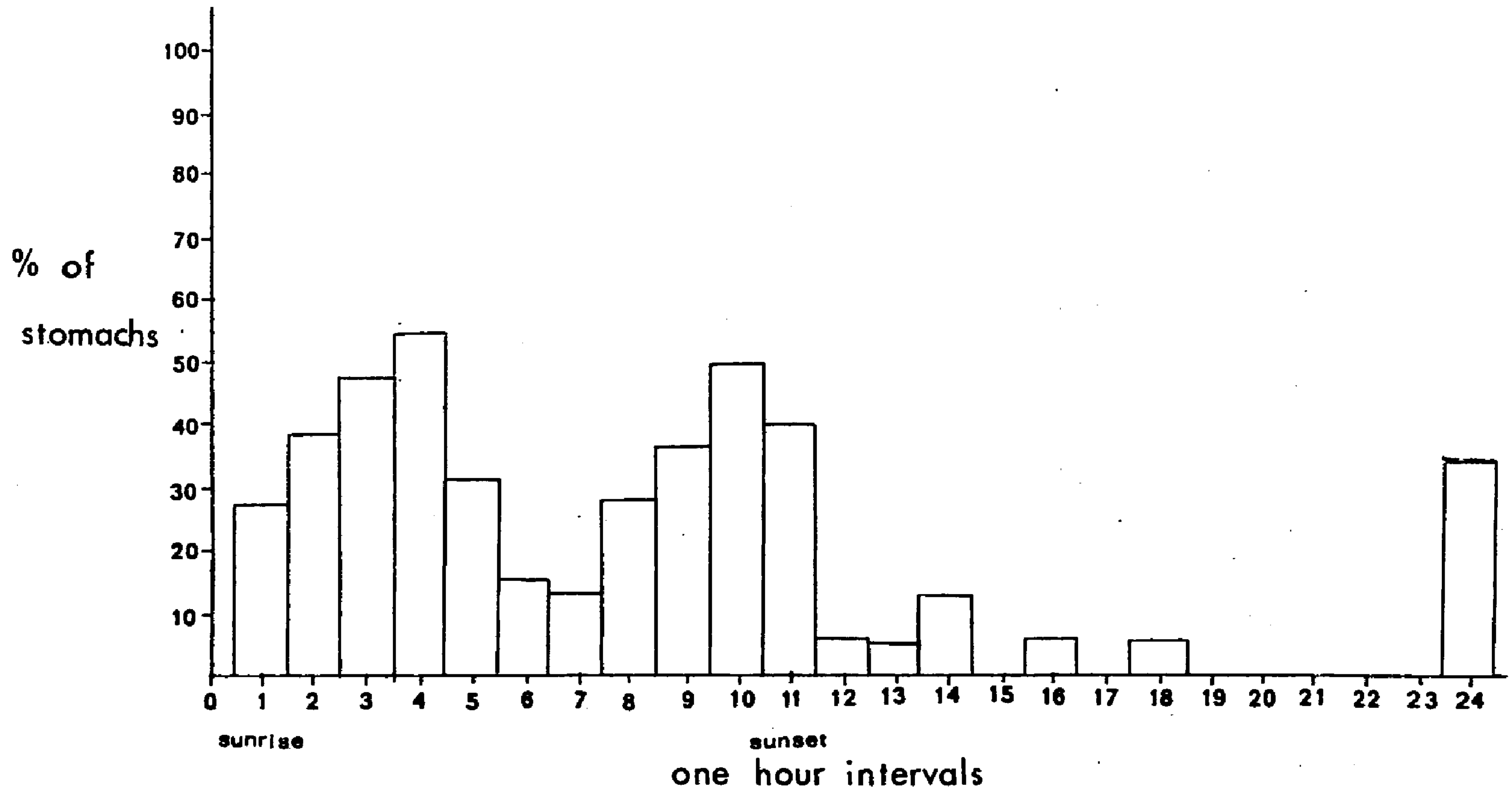


Fig. 39. Percentage frequency of unknown material in woodcock stomachs at hourly intervals.

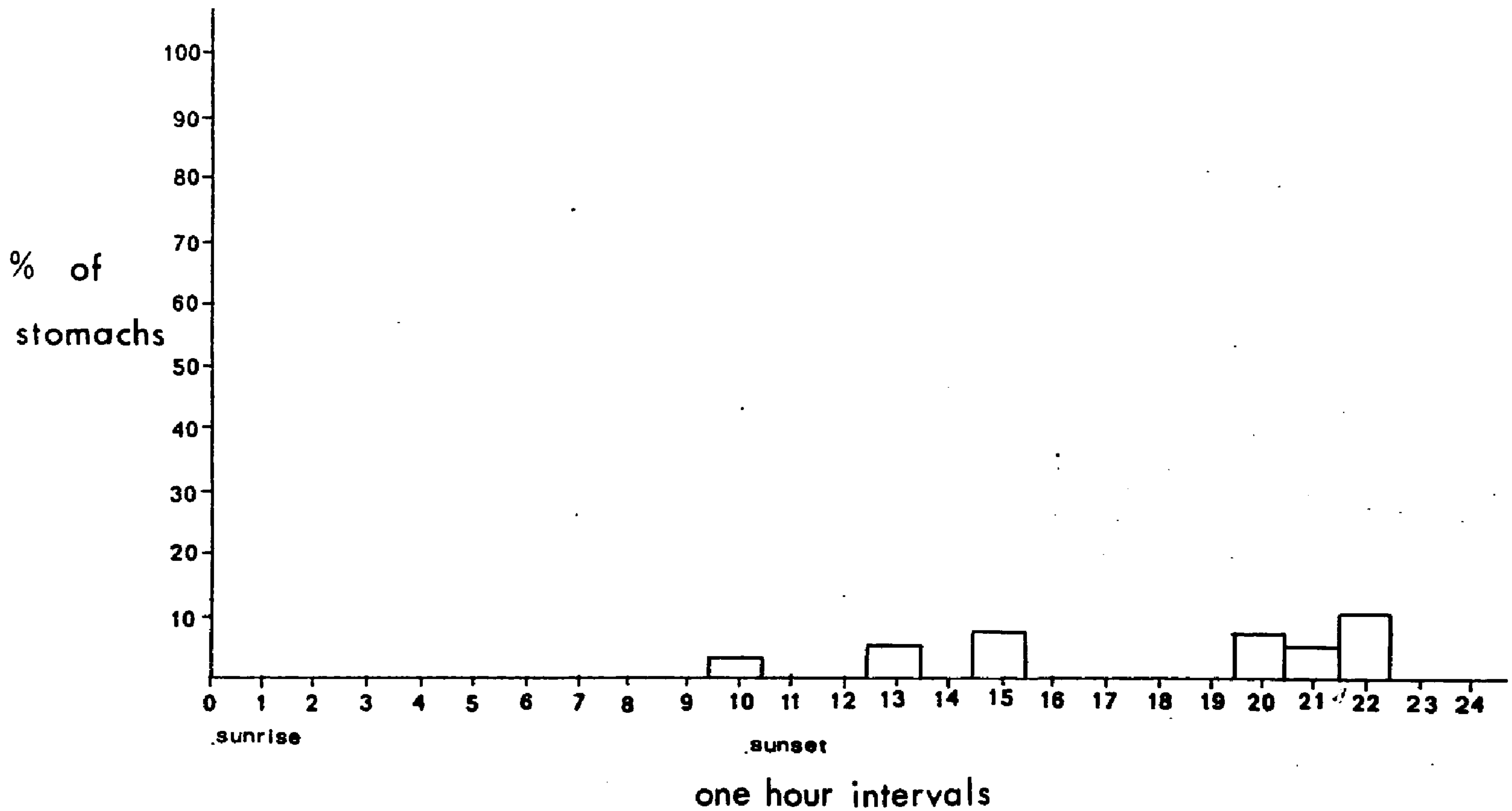


Fig. 40. Percentage frequency of horsefly larvae (Tabanidae) in woodcock stomachs at hourly intervals.

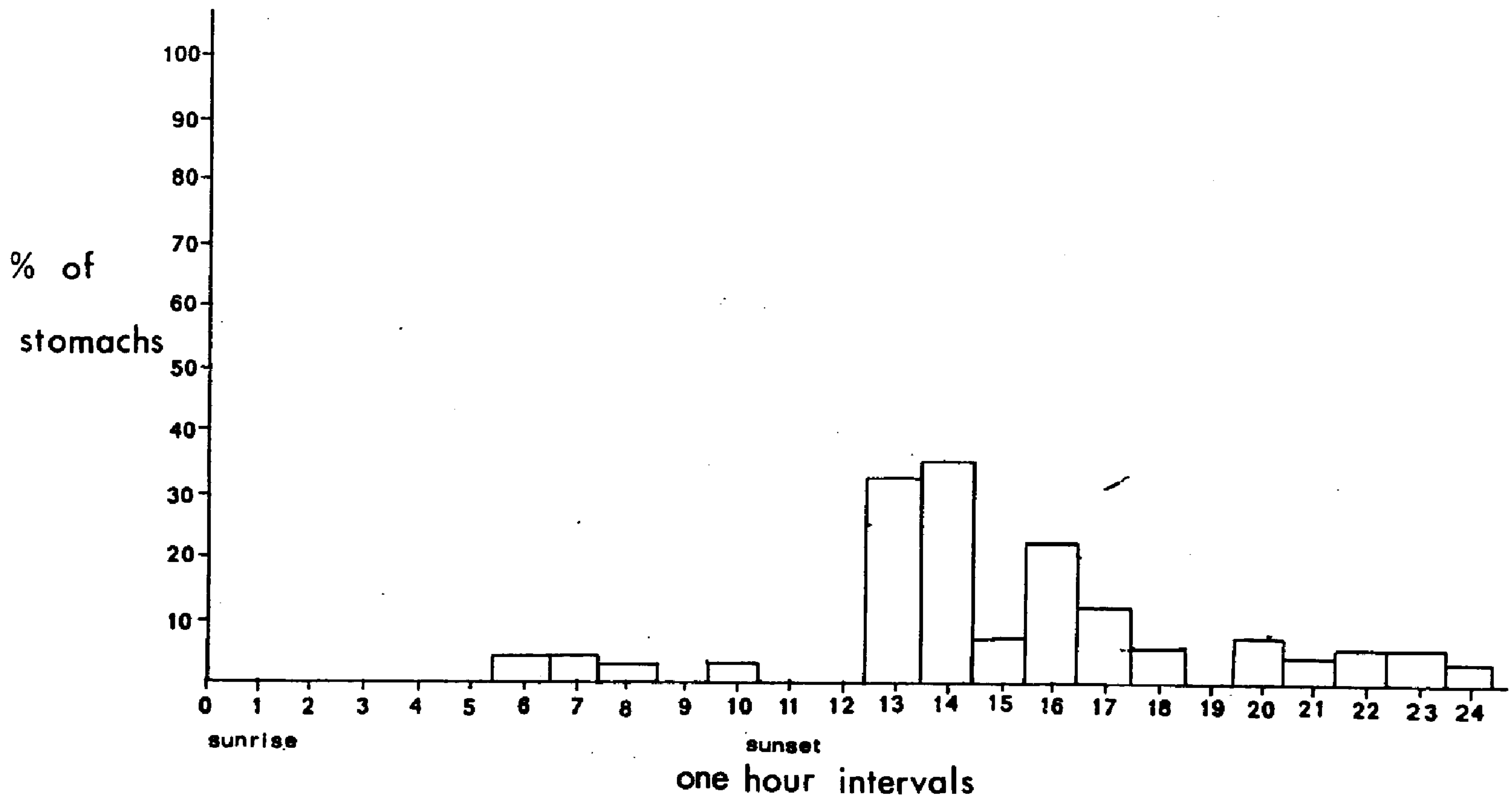


Fig. 41. Percentage frequency of moth and butterfly larvae (Lepidoptera) in woodcock stomachs at hourly intervals.

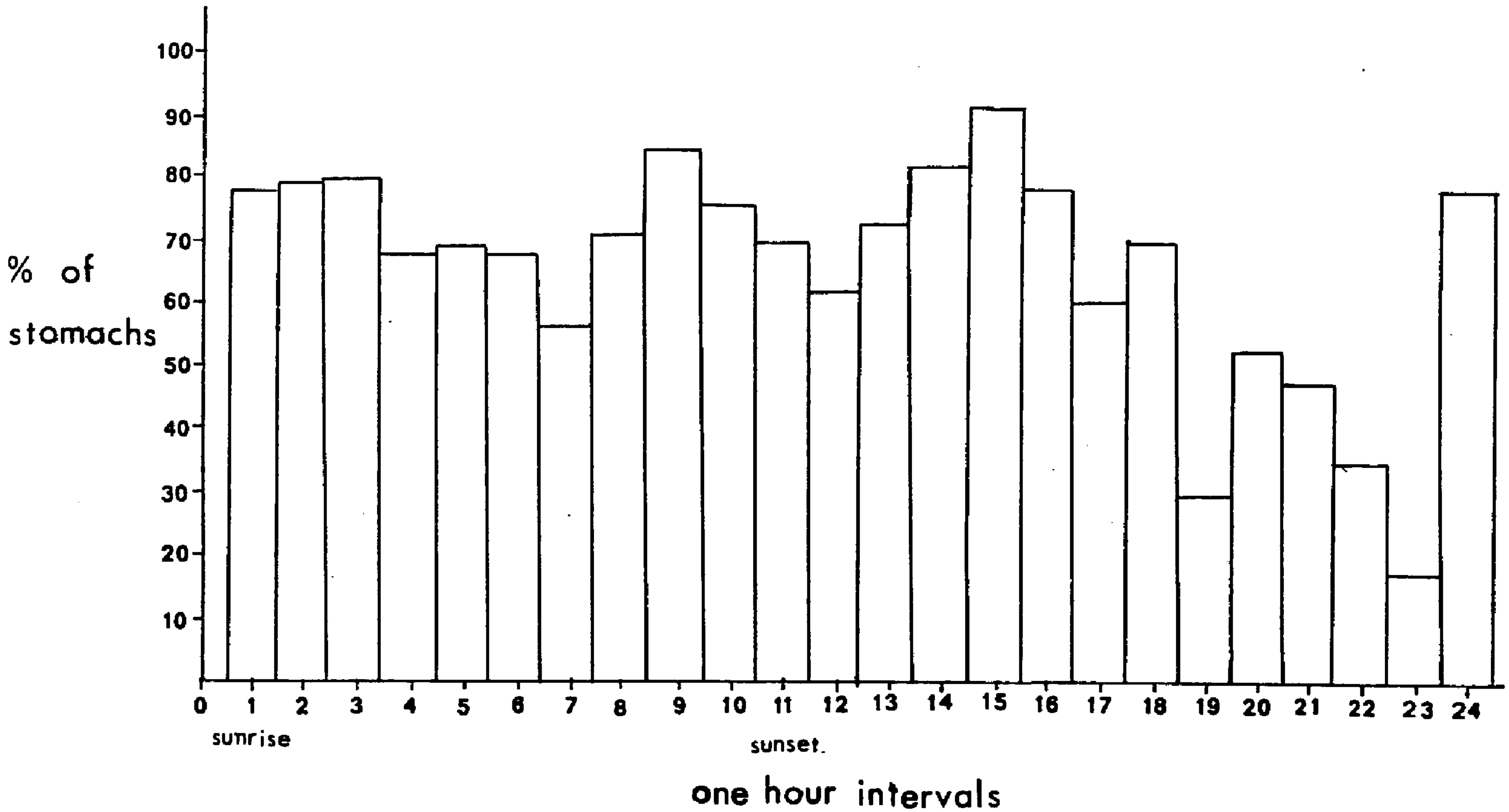


Fig. 42. Percentage frequency of ground beetles (Carabidae) in woodcock stomachs at hourly intervals.

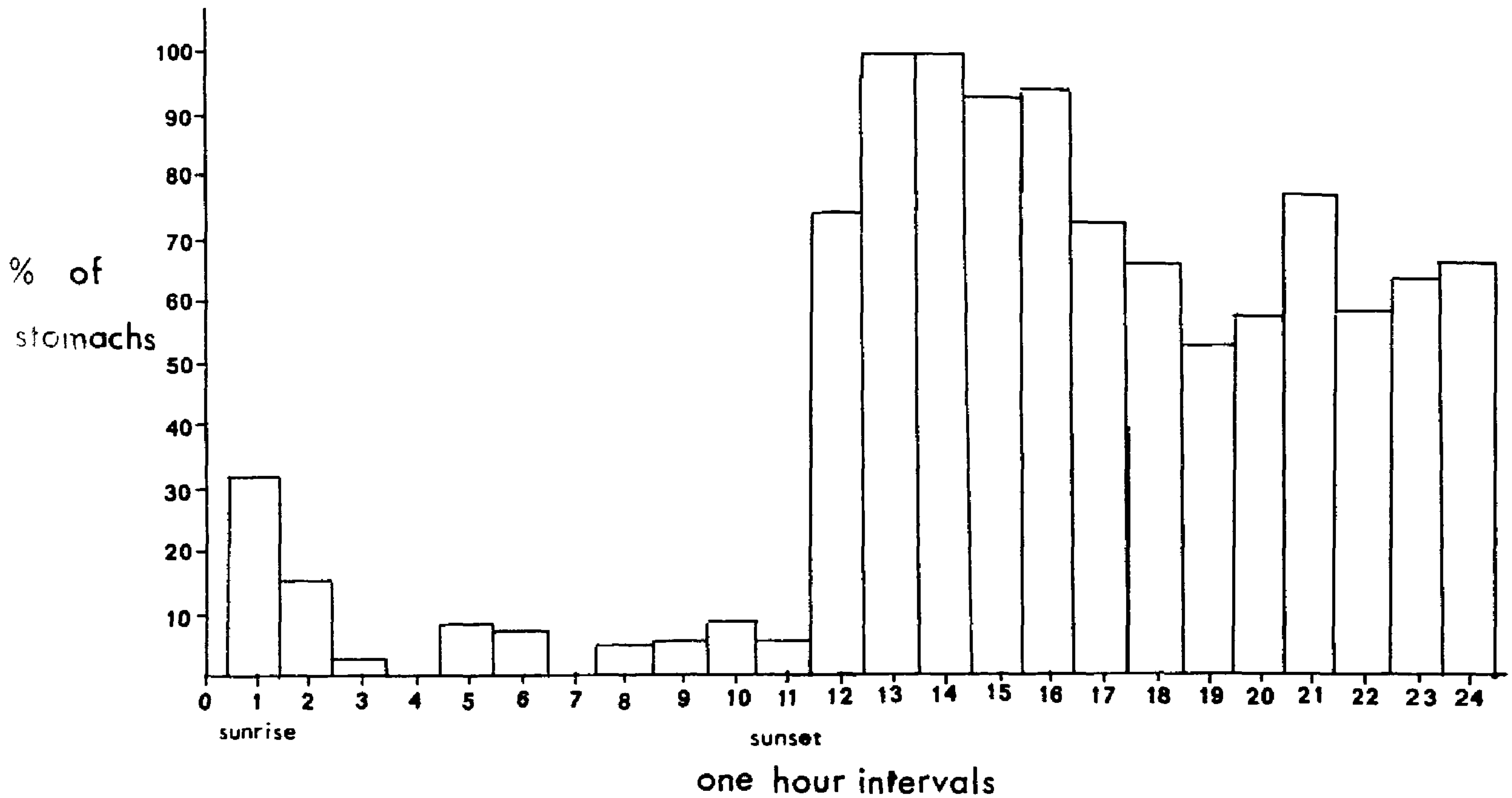


Fig. 43. Percentage frequency of fire ants (Solenopsis saevissima) in woodcock stomachs at hourly intervals.

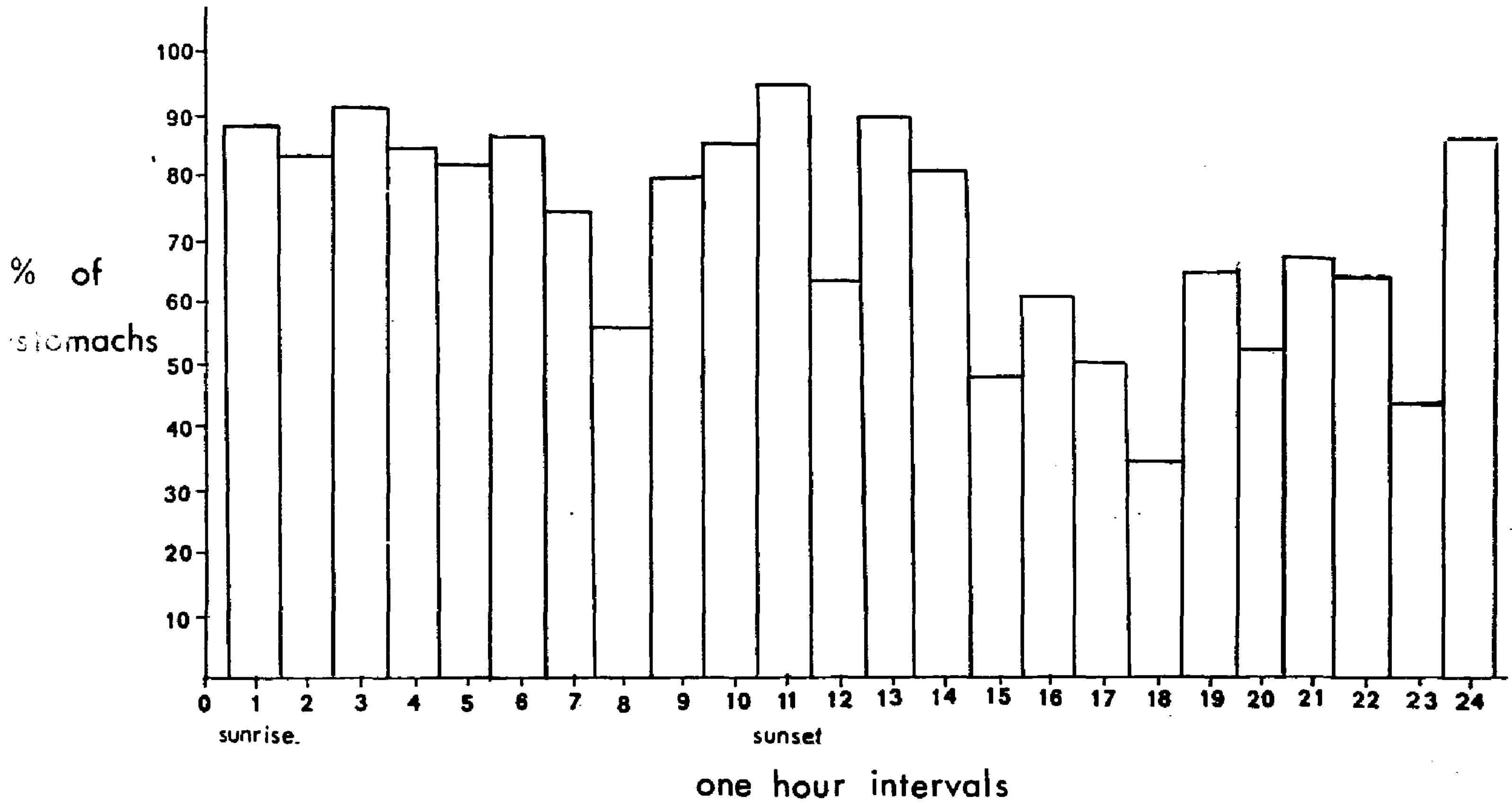


Fig. 44. Percentage frequency of earthworms (Oligochaeta) in woodcock stomachs at hourly intervals.

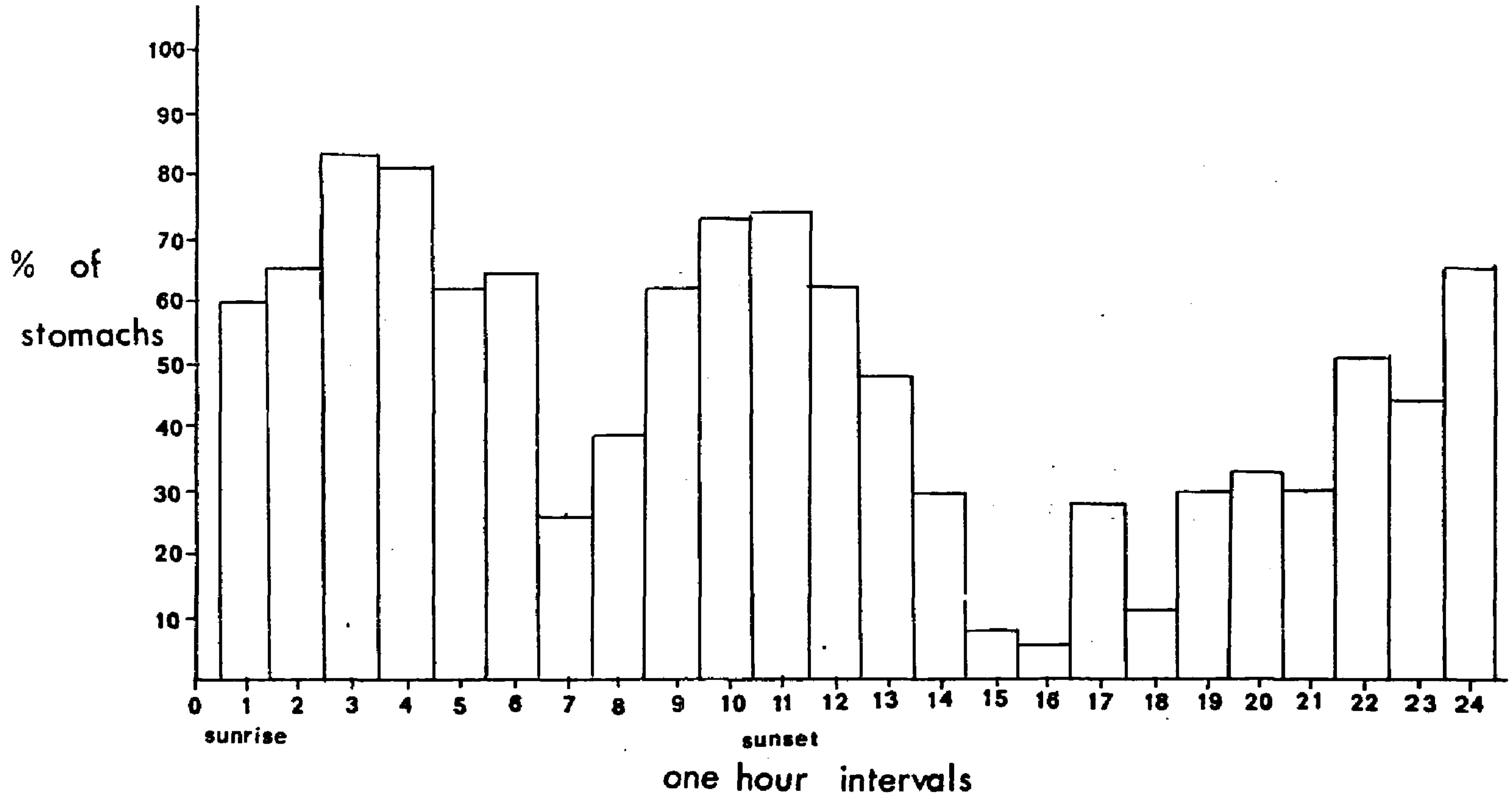
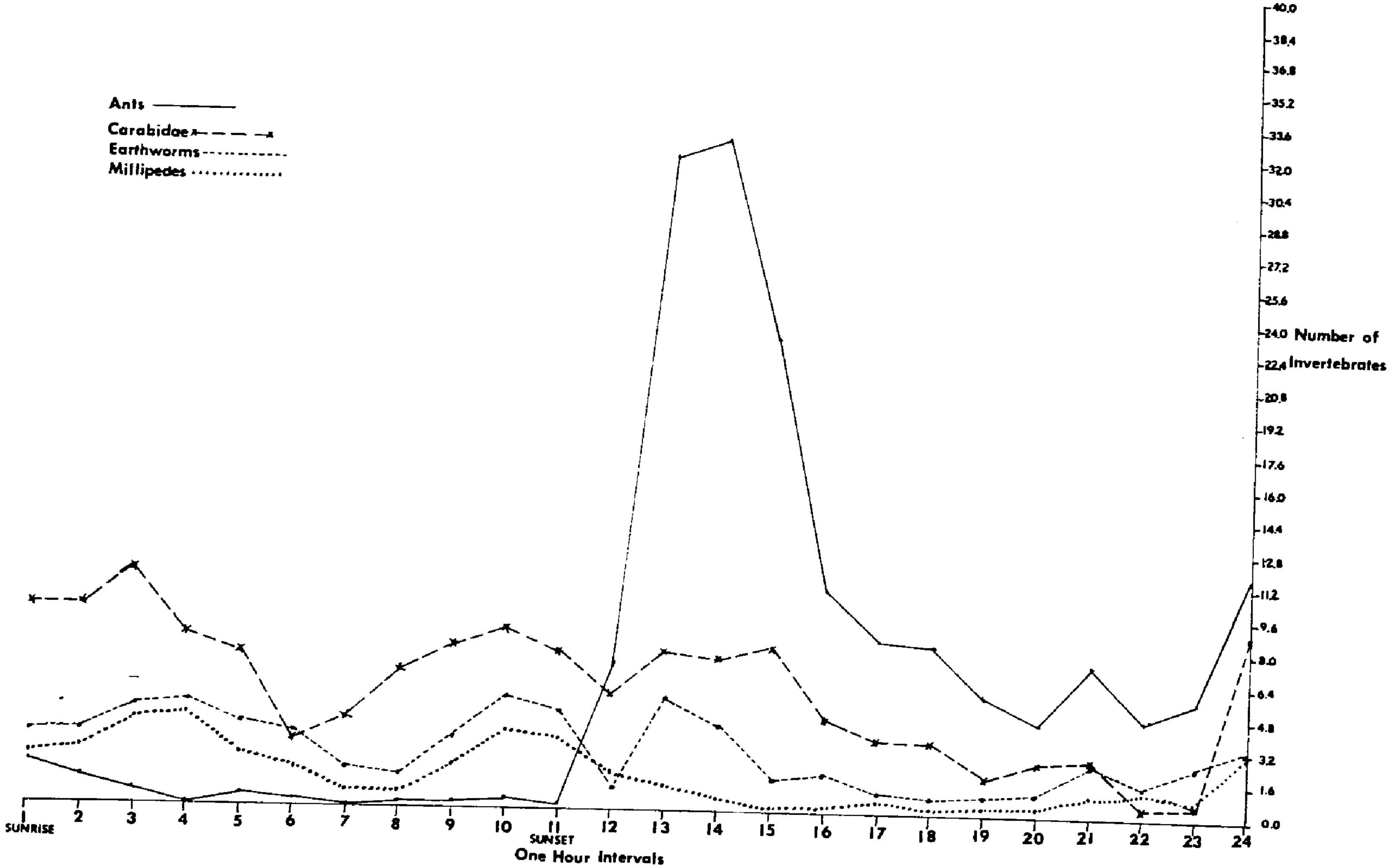


Fig. 45. Percentage frequency of millipedes (Diplopoda) in woodcock stomachs at hourly intervals.

ground beetles, earthworms, and millipedes follows the same general pattern. This pattern does not reflect the oscillations noted in the volumetric analysis and these items were probably consumed with equal frequency during all time periods. The consumption of the food items that caused the temporal oscillations, interpreted as feeding intervals, must therefore have been additive to these three food types. That is, the stomach volumes were relatively constant with respect to ground beetles, earthworms, and millipedes and the higher volumes observed for the feeding intervals were caused by other food types, one of which was fire ants (Fig. 46). The consumption of fire ants shows a marked increase immediately after sunset, followed by a rapid decline that stabilized about the fifth hour after sunset. This high rate of consumption is reflective of the evening feeding interval described in the volumetric analysis.

Another category of food items that occurred frequently enough to warrant special mention was seeds. A comparison of the amount of seeds consumed throughout the day indicated no apparent relationship between the amount of seeds in the stomachs and the time of day. Perhaps the difficulty with which certain seeds are digested, as compared to some of the animal material, was responsible for masking any relationship between amounts of seeds consumed and time of day. That is, seeds may have been consumed at intervals comparable to those identified for animal material, but the persistence of seeds in the stomach may have made the ebbs of the intervals unidentifiable. Four species of seeds occurred in more than 10 percent of the stomachs analyzed. These were: smartweed (Polygonum spp.) -- 13 percent, pigweed (Amaranthus spinosus) -- 11 percent, bahia grass (Paspalum notatum var.

Figure 46. Mean hourly numbers of four types of invertebrates commonly found in woodcock stomachs.


Ants
Carabidae
Earthworms
Millipedes
Number of Invertebrates
40.0
38.4
36.8
35.2
33.6
32.0
30.4
28.8
27.2
25.6
24.0
22.4
20.8
19.2
17.6
16.0
14.4
12.8
11.2
9.6
8.0
6.4
4.8
3.2
1.6
0.0
SUNRISE
2
3
4
5
6
7
8
9
10
11
SUNSET
12
13
14
15
16
17
18
19
20
21
22
23
24
One Hour Intervals

saurae) -- 13 percent, and curly dock (Rumex crispa) -- 11 percent. Seven other seed species were identified from the 677 stomachs. The numbers-per-stomach of the various seed species provided substantial evidence that these seeds were not being ingested accidentally. The mean numbers-per-stomach for the four most frequently occurring seed species were: smartweed - 11, pigweed - 9, bahia grass - 26, and curly dock - 13. Several stomachs were examined that contained no identifiable material other than seeds (Fig. 47). Although these seeds often made considerable contributions to the total stomach volumes, the fact that there seemed to be no periodicity associated with their consumption neither added to nor detracted from the periodic feeding conclusions drawn from the volumetric analyses.

Some of the material, both plant and animal, identified from woodcock stomachs was undoubtedly acted upon by the digestive process in varying ways. For instance, the carapace of beetles or the coating of seeds would be acted upon more slowly by digestive action than would the tissues of earthworms. Perhaps, therefore, some of the values for those food items of a more resilient constitution may be slightly inflated, thereby creating sampling error. Regardless of this error, the data for the types of food consumed demonstrates that woodcock are somewhat nonspecific feeders in that they feed on material indigenous to whatever habitat they occupy.

Types of foods reported in previous studies

Almost 40 years ago, workers in the northeast United States and southeast Canada reported similarities between the food habits of woodcock in their respective regions. Pettingill (1936) found that 86 percent of the contents of woodcock stomachs were composed of earthworms.

Figure 47. Total contents of woodcock stomach No. 231; bahia grass seeds, smartweed seeds, and curly dock seeds.

Aldous (1936) reported that earthworms composed 86 percent of the stomach contents of 63 woodcock stomachs collected in October.

Miller (1957) analyzed 115 woodcock stomachs during the fall of 1955 in Pennsylvania and found that 73 percent of the volume of the stomach contents was composed of plant debris. In 1956 he found that 60 percent of the volume of 46 woodcock stomachs consisted of plant debris. Of the 190 woodcock stomachs he analyzed between 1954 and 1956, 135 contained seeds of blackberry or sedge (Carex spp.). Sperry (1940) collected 261 stomachs from the northeast United States and southeast Canada over an extended period of time and found that earthworms comprised 70 percent of all foods.

Liscinsky (1956) expressed the opinion that woodcock distribution may be dependent on the availability of earthworms in a particular habitat. Sheldon (1967) felt that there may be a correlation between earthworm occurrence and the presence of woodcock only if other habitat requirements are met. He pointed out that if woodcock are now dependent on earthworms for their primary food supply, then woodcock must have changed their food preferences after the arrival of the colonists in the northeast United States. This statement is based on historic evidence indicating that no known species of earthworm existed in the northeast United States prior to its introduction by the colonists. This evidence lends credence to his theory that the woodcock is basically an opportuntic feeder. That is, they will eat any material, plant or animal, capable of satisfying their nutritional requirements.

Sheldon (1967) has observed woodcock eating ants from the ground surface and attempting to catch insects flying around a light at night. He located fields that were used nocturnally during the summer months and noted, "A 3 acre field was relatively bare, having been scraped by a bulldozer 10 years before; on this, the only food appeared to be ants. The larger fields were covered with grass clumps. All these sites were dry, so woodcock fed from prey on the ground surface." He collected 15 woodcock that had been feeding on insects and invertebrates other than earthworms, the most common of which was beetle larvae. Sperry (1940) found that the percent of insects in woodcock stomachs increased during the course of the summer so that by August, the stomachs he collected averaged 38 percent insects. He felt that the importance of insects increased during the late summer months possibly due to the reduced precipitation. More recently, Krohn (1970) collected 36 woodcock stomachs in Maine and found a higher percent of beetles (Coleoptera) than in previous works done in this same region during the fall months. He gave two possible explanations for this change of frequency. First, beetles are more common during the summer months, and secondly, the birds he collected were taken at night while other workers made their collections during the day.

Glasgow (1958), working on the wintering grounds in southeast Louisiana, stated that earthworms make up the majority of the diet of woodcock. However, he found that cover rather than earthworm abundance may be more important to selection of nocturnal-use fields. Another Louisiana study by Ensminger (1954) substantiated this contention. He found that earthworms were as abundant in fields that received no nocturnal woodcock usage as in fields that were used heavily. He concluded that cover in fields controlled the degree of nocturnal use. Owens (1967) found that earthworms were very common in all fields, whether they were used by woodcock or not.

Britt (1971) determined that earthworms were not as important to the diet of wintering woodcock as several previous studies had indicated. He concluded that the large quantities of plant material and seeds found in stomachs that he collected made the possibility of incidental ingestion of this material highly unlikely. He, like Sheldon (1967), concluded that woodcock are opportunistic feeders.

Conclusions regarding types of foods

The wide variety of material extracted from woodcock stomachs substantiates the findings of several previous workers that the woodcock is an opportunistic feeder. Although there were changes in types of material consumed between the different habitat types, the volumes determined for each peak of each feeding interval were very similar, thereby suggesting that habitat is not chosen on the basis of the occurrence of a particular food item. Also, the fact that woodcock exhibited very narrow tolerances for certain habitat variables, as discussed previously in this report, suggests that site characteristics may be more important for governing the use of a particular habitat by woodcock than the presence or absence of certain food items. These conclusions corroborate the findings of several of the more recent woodcock studies.

Relationship of Food Items to Habitat

In an effort to recognize any correlation between types of material ingested and the availability of this material in the environment, stomach contents were compared to material extracted from flushing points, which were in turn compared to the contents of the random plots.

The data for the stomach contents were collected on a 24 hour basis while the material extracted from the sampling plots was collected only during the daylight hours. Thus, to compare the food consumed in diurnal habitat to the occurrence of food items in diurnal habitat, stomachs collected during nocturnal intervals were removed from consideration. Of the four most frequently consumed food items: earthworms occurred with approximately the same frequencies in woodcock stomachs as on the flushing points; ground beetles and millipedes occurred with much higher frequencies in woodcock stomachs than on flushing points; and fire ants occurred with about the same regularity in stomachs collected during the day as on the flushing points (although consumption during nocturnal periods inflated their percent occurrence for the total stomachs) (see Table 17). Because ground beetles and millipedes were found in a much higher percent of stomachs than their frequency of occurrence in the environment suggests, they must be considered preferred food items. Earthworms, although obviously a preferred food item, are apparently not pursued with the same intensity as the ground beetles and millipedes. Fire ants are not apparently a preferred food in diurnal cover and the higher occurrence for this species on the random plots compared to the flushing points suggests that diurnal habitat is composed of sites not favorable for the occurrence of fire ants. Thus, any preference woodcock may have for fire ants may be disguised in this analysis by a preference for sites not conducive to fire ant occurrence. Earthworms, ground beetles, and millipedes were apparently consumed as frequently in nocturnal cover as in diurnal cover. Without data on the frequency of occurrence of fire ants in the nocturnally-used fields, speculations about how frequently they were consumed in relation to their abundance are inappropriate.

Table 17. A comparison of invertebrates taken from 677 woodcock stomachs, 202 points from which woodcock were flushed, and 70 random plots.

Item	Percent of stomachs in which item occurred		Percent of flushing points on which item was found	Percent of random plots on which item was found
	(Total)	(Diurnal)		
Crickets (Gryllidae)	0		7	9
Earthworms (Oligochaeta)	76	31	38	27
Spiders (Araneida)	4	0	12	22
Cranefly larvae (Tipulidae)	22	9	12	9
Soldierfly larvae (Stratiomyidae)	4	1	27	9
Moth larvae (Lepidoptera)	4	0	9	6
Beetles (Coleoptera)	0	0	17	12
Centipedes (Chilopoda)	0	0	22	14
Fire ants (*Solenopsis saevissima*)	42	3	6	14
Snails (Gastropoda)	17	7	14	21
Firefly larvae (Lampyridae)	0	0	0	7
Horsefly larvae (Tabanidae)	1	0	1	0
Ground beetles (Carabidae)	69	42	1	7
White grubs (*Phyllophaga* sp.)	9	3	1	10
Millipedes (Diplopoda)	54	31	1	1
Unknown	26	17	27	28

The remaining 11 invertebrate food types were consumed much less frequently than were the earthworms, millipedes, ground beetles, or fire ants. The cranefly larva and snails were consumed with approximately the same regularity in nocturnal and diurnal habitat (see Figs. 36 and 37). The frequencies with which these items occurred in woodcock stomachs were equal to or slightly less than the frequencies with which they occurred on the flushing points and random plots. These data suggest that they were not highly preferred food items. The consumption of the remaining nine invertebrate groups was of such a low frequency that conclusions regarding their value as food items is questionable. However, the high frequency of occurrence on the flushing points for soldierfly, larva, beetles, centipedes, and snails, coupled with their extremely low frequency of occurrence in woodcock stomachs, indicates that these items are definitely not preferred food items and may indeed be selected against.

Seeds were consumed mainly during the diurnal sampling intervals with the exception of pigweed (see Table 18). A comparison of the occurrence of seeds in stomach samples to their occurrence on both types of sampled plots shows that consumption was more closely allied with seed distribution on the random plots than on the flushing points. This suggests that the consumption of seeds is something of a random process and that in all probability habitat is not chosen on the basis of seed occurrence. Four types of seeds occurred on both types of sampled plots and not at all in woodcock stomachs. These were sugarberry, nightshade, ragweed, and oaks. Considering the extremely high frequency of sugarberry, particularly on the random plots, this species should have occurred in a few woodcock stomachs had the consumption of seeds been a

Table 18. A comparison of seeds taken from 677 woodcock stomachs, 202 points from which woodcock were flushed, and 70 random plots.

Item	Percent of stomachs from which item was extracted (Total)	(Diurnal)	Percent of flushing points on which item was found	Percent of random plots on which item was found
Swamp smartweed (Polygonom pennsylvanicum)	3	2		
Smartweed (Polygonum sp.)	13	11		
Pigweed (Amaranthus spinosus)	11	4	1	12
Bahia grass (Paspalum notatum var. saurae)	13	12	1	8
Morning glory (Ipomoea sp.)	3	2		
Curly dock (Rumex crispa)			1	13
Sesbania (Sesbania exaltata)	2	2		
Thistle (Carduus sp.)	4	4		
Festuca (Festuca sp.)	6	4		
Wild geranium (Geranium sp.)	1	1	1	3
Greenbrier (Smilax sp.)	5	4	1	10
Sugarberry (Celtis laevigata)			11	71
Nightshade (Solanum sp.)			7	13
Oaks (Quercus sp.)			1	26
Ragweed (Ambrosia sp.)			2	20

purely incidental phenomenon. The absence of acorns in woodcock stomachs is undoubtedly attributable to their large size. The higher frequencies recorded for the random plots for all seed species serves as another illustration that flushing points had certain characteristics unlike the typical or random site sampled.

A comparison between flushing points and random plots for all invertebrate and seed groups was conducted by means of a t-test. Of the 15 groups of invertebrates identified from the flushing points and the random plots, four of them (27 percent) had significantly different distributions between the flushing points and random plots (see Table 19). Of the nine groups of seeds found on both types of sampled plots, six of them (67 percent) had significantly different distributions between the flushing points and random plots. Of the four invertebrate groups with significantly different distributions, three were more prevalent on the random plots.

Although an attempt to classify differences of sites on the basis of these differences of food items is inappropriate, there are characteristics of points from which woodcock were flushed that are different from the random sites. However, the lack of correlation between food items found on flushing points and those found in woodcock stomachs indicates that the differences between flushing points and random plots is probably not related to the dietary habits of woodcock. Considering the differences of soil moisture and vegetative associations between the random plots and the flushing points, the differences between sampled sites for invertebrates and seeds is probably related more to site characteristics than to preferences by woodcock for certain food items.

Table 19. Food items that had significantly different distributions on flushing points than on random plots.

Item	Results of t-test ($p < .05$)
Soldierfly larvae	Significantly more on flushing points
Fire ants	Significantly more on random plots
Firefly larvae	Significantly more on random plots
White grubs	Significantly more on random plots
Nightshade seeds	Significantly more on random plots
Ragweed seeds	Significantly more on random plots
Oak acorns	Significantly more on random plots
Sugarberry seeds	Significantly more on random plots
Pigweed seeds	Significantly more on random plots
Curly dock seeds	Significantly more on random plots

Local Movements in Response to Climatic Changes

Although a preference for specific habitat variables has been outlined, there may be reason to believe that changes of the occupancy of broad areas or regions of winter habitat may be controlled by climatic conditions. Reid and Goodrum (1955), working in Vernon, Natchitoches, and Rapides parishes of central Louisiana, noted that winter rains are important for determining which type of wintering habitat woodcock will choose. They observed that during dry periods woodcock vacated post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) hillsides and chose low-lying, moister areas.

Another climatic factor that has been more frequently associated with local movements is temperature. Glasgow (1958) observed more woodcock in the bottomland hardwood habitats of southeast Louisiana following an early winter cold front. Several workers have reported dramatic shifts of habitat as the result of severe cold spells in southern Louisiana. McIlhenny (1940) and Mendall and Aldous (1943) noted that many woodcock died as the result of the freeze of 1940 in southern Louisiana. They commented on the large concentrations of woodcock in the coastal parishes during this period. During late January of 1951, Louisiana received another severe cold wave that lasted 5 days. During this period, Lynch (1952) located 357 woodcock in 11 hours on Cheniere au Tigre, an island located in extreme south Louisiana separated from the mainland by 30 miles of marsh. Glasgow (1958) found few woodcock in nocturnal banding fields until about a week after this storm had passed. Goodrum and Reid (1952) observed that woodcock in west central Louisiana vacated hillside habitats in favor of brushy areas around unfrozen water during this cold wave. More recently, I observed large numbers of woodcock on the landing strip at Rockefeller Wildlife Refuge in extreme south Louisiana during a 4 day cold wave in early January of 1973.

Although the shifts in habitat as a result of major climatic aberrations are well documented, no information is available on responses of woodcock to climatic changes of a lesser magnitude or of a shorter duration. Because these could conceivably have a substantial impact on the types of habitat utilized or the amount of habitat available for use, data were collected on localized movements.

Two hundred woodcock were caught from the nocturnally used field at Grosse Tete, Louisiana and marked with flourescent backtags. Fourteen of these were returned by hunters and questionnaires were then sent to these hunters requesting that the time and location of collection of the marked woodcock be given. Eight of these returns came from within 5 miles of the initial capture site, four returns were from approximately 50 miles south of the capture site, and two returns were from approximately 40 miles north of the capture site. The temperatures for the 3 days prior to the recovery date were then compared to the recovery location. A definite southward movement in response to cold temperatures and a possible northward movement in response to warmer temperatures was identified (see Table 20).

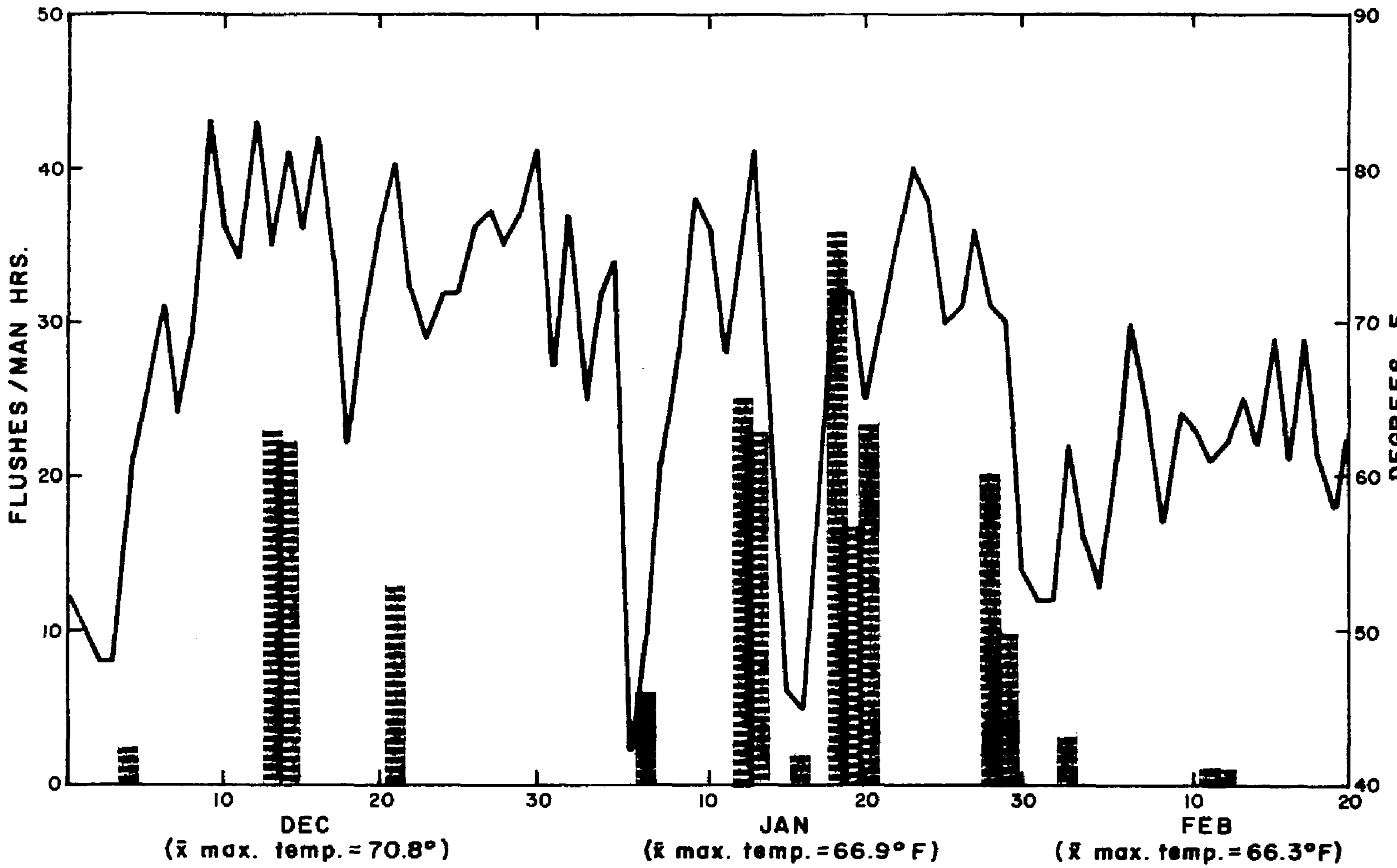
In further attempts to recognize any movements or shifts of populations in response to local climatic changes, records were maintained on the numbers of woodcock flushed from nocturnally used fields during the course of this study and these numbers were then plotted against daily temperatures. These data suggest that the numbers of woodcock decrease following periods of low temperatures (see Figs. 48, 49,

Table 20. Dates and locations of returns of backtags affixed to woodcock in southern Louisiana.

Marking Date	Marking Location	Recovery Date	Return location and distance from banding location	Mean maximum temperature for 3 days prior to recovery	
12/10/72	Grosse Tete, La.	01/05/73	Grosse Tete, La. -- same	61.6°F	
11/29/72	Grosse Tete, La.	01/07/73	Grosse Tete, La. -- same	67.0°F	
12/12/72	Grosse Tete, La.	12/26/72	Grosse Tete, La. -- same	60.6°F	
12/10/72	Grosse Tete, La.	12/18/72	Musson, La. -- 6.5 mi. WNW	62.7°F	66.1°F (1)
11/27/72	Grosse Tete, La.	01/05/73	Grosse Tete, La. -- same	61.6°F	
11/27/72	Grosse Tete, La.	01/17/73	Grosse Tete, La. -- same	67.6°F	
12/12/72	Grosse Tete, La.	01/20/73	Grosse Tete, La. -- same	74.0°F	
12/09/72	Grosse Tete, La.	01/19/73	Ramah, La. -- 4.5 mi. W	74.0°F	
12/12/72	Grosse Tete, La.	01/12/73	Charenton, La. -- 37 mi. S	34.0°F	
12/10/72	Grosse Tete, La.	01/12/73	Oaklawn, La. -- 39 mi. S	34.0°F	39.1°F (2)
12/10/72	Grosse Tete, La.	01/13/73	Charenton, La. -- 37 mi. S	37.0°F	
11/27/72	Grosse Tete, La.	01/15/73	Baldwin, La. -- 40 mi. S	51.3°F	
12/12/72	Grosse Tete, La.	01/22/73	New Roads, La. -- 22 mi. N	71.3°F	72.6°F (3)
11/23/72	Grosse Tete, La.	01/20/73	Innis, La. -- 35 mi. N	74.0°F	

(1) Mean temperature of 3 days prior to recoveries from marking vicinity.
(2) Mean temperature of 3 days prior to recoveries from areas south of marking location.
(3) Mean temperature of 3 days prior to recoveries from areas north of marking location.

Figure 48. A comparison of flushes-per-man-hour in nocturnal fields to temperatures for the winter of 1971-72.



FLUSHES / MAN HRS.
0
10
20
30
40
50
DEGREES, F
40
50
60
70
80
90
10
20
30
DEC
(x̄ max. temp. = 70.8°)
10
20
30
JAN
(x̄ max. temp. = 66.9° F)
10
20
FEB
(x̄ max. temp. = 66.3°F)

Figure 49. A comparison of flushes-per-man-hour in nocturnal fields to temperatures for the winter of 1972-73.

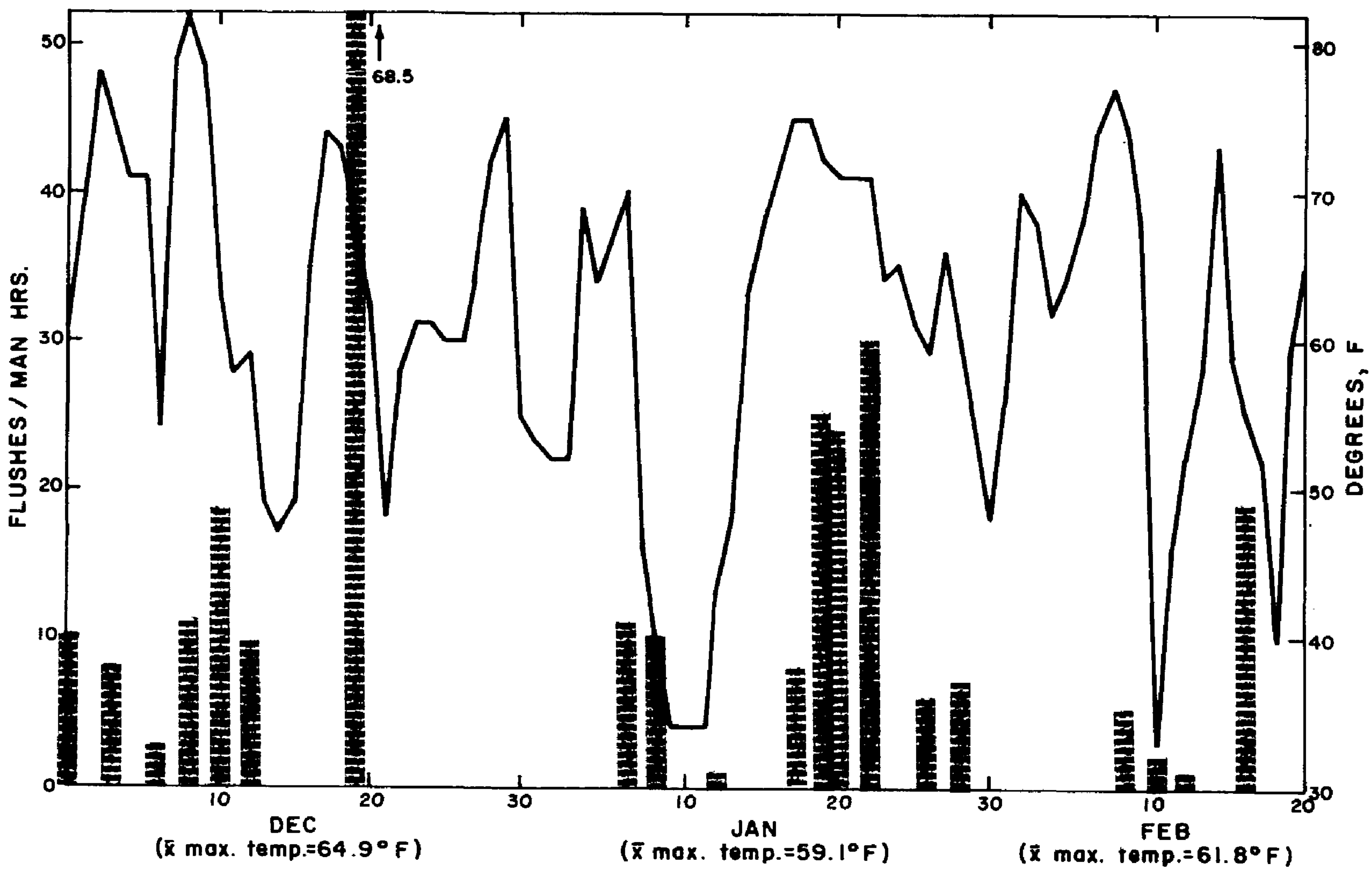
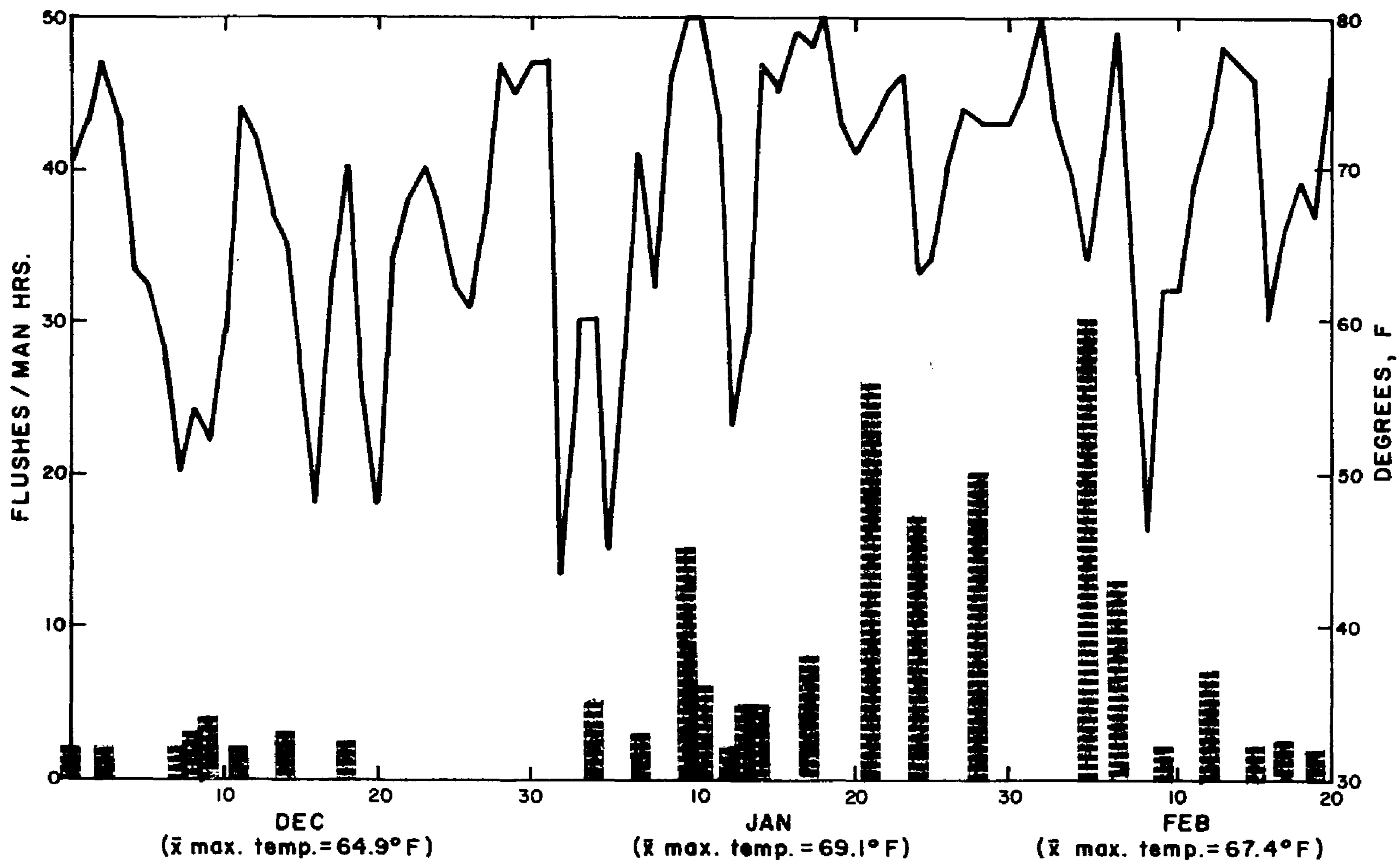

FLUSHES / MAN HRS.
DEGREES, F
68.5
DEC
(x̄ max. temp.=64.9°F)
JAN
(x̄ max. temp.=59.1°F)
FEB
(x̄ max. temp.=61.8°F)

Figure 50. A comparison of flushes-per-man-hour in nocturnal fields to temperatures for the winter of 1973-74.


FLUSHES / MAN HRS.
DEGREES, F
DEC
(x̄ max. temp.=64.9°F)
JAN
(x̄ max. temp.=69.1°F)
FEB
(x̄ max. temp.=67.4°F)

and 50). An example of this fluctuating number of woodcock is provided by January of 1973 when it was abnormally cold early in the month and few woodcock were seen. Later in the month the temperatures were higher and more woodcock were seen. January of 1972 had two abnormally cold periods, which resulted in marked reductions in the number of woodcock seen; however, the numbers increased in both cases as the temperatures warmed. The winter months of 1973-74 were all warmer than the winter months of the 2 previous years and fewer woodcock were observed during that year. Also, the peak number of woodcock sightings occurred in late January and early February rather than in mid-January as in the previous 2 years.

These observations support the movement trends alluded to by the information obtained from the backtagged woodcock. All these data indicate that localized movements do occur in response to climatic changes, thereby suggesting that wintering habitats other than bottomland hardwoods may be important during certain climatic conditions.

Breeding Activity

Nesting Activity

Evidence is available to indicate that woodcock may breed with some regularity in Louisiana. Incidences of nests or females with young in Louisiana have been reported by Beyer et al. (1908), Pettingill (1936), Merovka (1939), Norris (1941), Mendall and Aldous (1943), Van Pelt (1951), and Glasgow (1958). During February, March, and April of 1950 through 1954, Reid and Goodrum (1953, 1954) observed 11 nesting females and 24 young woodcock in central Louisiana. Lowery (1974) has noted that woodcock do breed in Louisiana, but only rarely. Glasgow (1958) reported that hunters sometimes kill females in January that are carrying eggs. In light of these observations, cooperators were solicited to report evidence of nesting in various parts of Louisiana. Also, certain hunters were asked to report any evidence of female woodcock carrying eggs during the hunting season in Louisiana.

Sixteen wildlife biologists, professional foresters, and wildlife refuge managers from all parts of Louisiana were contacted and asked to detail any information in their possession regarding nesting activity. Fourteen reported either seeing nests or receiving nesting reports from reliable sources. Nine of these cooperators knew of a minimum of 15 verified nesting efforts and four knew of more than 25 nesting attempts. Seven of the 16 biologists knew of successful hatchings and brood rearings in Louisiana. Although the locations from which these biologists worked were scattered throughout the state, the majority (87 percent) of the 221 reported nests were from north of an East-to-West line drawn through Alexandria, Louisiana (Fig. 51). There were only four reports south of an East-to-West line drawn through Baton Rouge, Louisiana. Some of these reports dated back 27 years and there was no apparent correlation between a year or group of years and nesting frequency. Although considerable time was spent during February, March, and April of the years of this study in the vicinity of the three areas used for this study, only one nest was located (Fig. 52). This nest was located under a sparse hardwood overstory on the second terrace of the Mississippi River flood plain 12.7 miles north of Baton Rouge, Louisiana. This nest was monitored daily until it was destroyed by a mammalian predator.

Figure 51. Distribution of 221 nesting reports in Louisiana for a 27 year period.

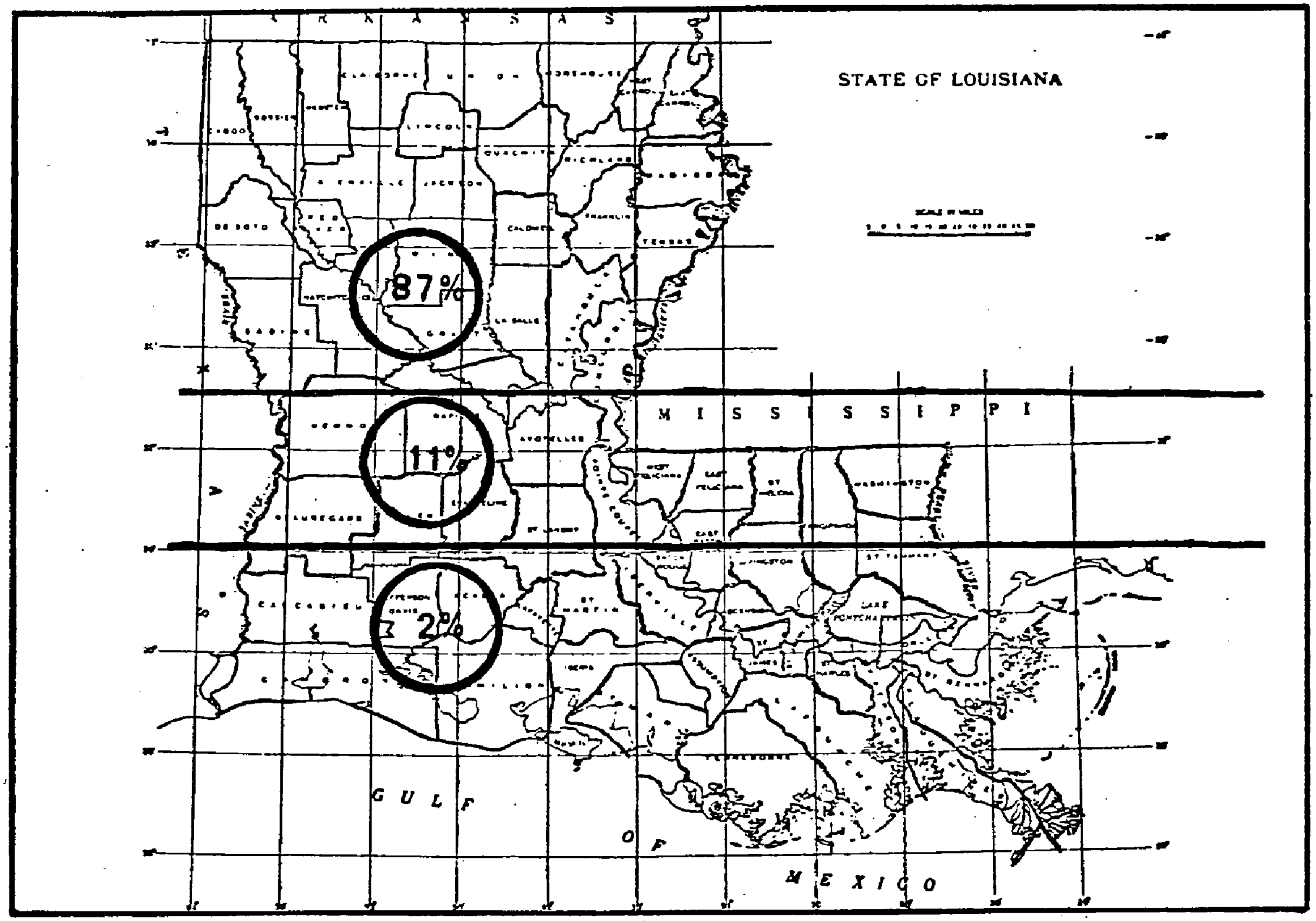

STATE OF LOUISIANA
A R K A N S A S
87%
11%
2%
M I S S I S S I P P I
G U L F
O F
M E X I C O

Figure 52. Habitat surrounding a woodcock nest located 12.7 miles north of Baton Rouge, Louisiana.

To further explore nesting activity in Louisiana, 35 woodcock hunters who hunted in Louisiana were contacted and asked whether they had collected female woodcock that were carrying eggs. All these hunters were carefully chosen and I consider their reports reliable. Of these 35 contacts, six had shot females with eggs during the hunting season and 12 had heard of other hunters doing so. These solicitations resulted in a total of 26 confirmed reports dating back 9 years. No localization of these reports existed as 41 percent came from areas north of an East-to-West line drawn through Alexandria, Louisiana and 59 percent were from areas south of this line. A comparison of these reports to general climatic conditions did not reveal any correlation between weather and reproductive conditions. Few of these hunters were able to recall specific dates; however most (93%) said these woodcock were shot during the last week of January or the first week of February.

Testes Development

One of the best indicators of reproductive condition of male birds is the degree of testicular enlargement. Marshall (1961) noted that avian testes may increase up to 360-fold in size in some species during the breeding season. Pettingill (1970) stated that during the breeding season, testes increase greatly in circumference, more than doubling in size. Monitoring seasonal variation in testes size therefore seemed to be appropriate method for analyzing breeding condition of Louisiana woodcock.

Testes were removed from 17 male woodcock in 1972-73 and from 24 woodcock in 1973-74. Comparisons of volumes between these 2 years, as well as with 37 testes removed from woodcock collected during the breeding season in Maine, indicated that the volumes from 1972-73 in Louisiana were significantly lower than the volumes for 1973-74 in Louisiana or those for Maine (Fig. 53).

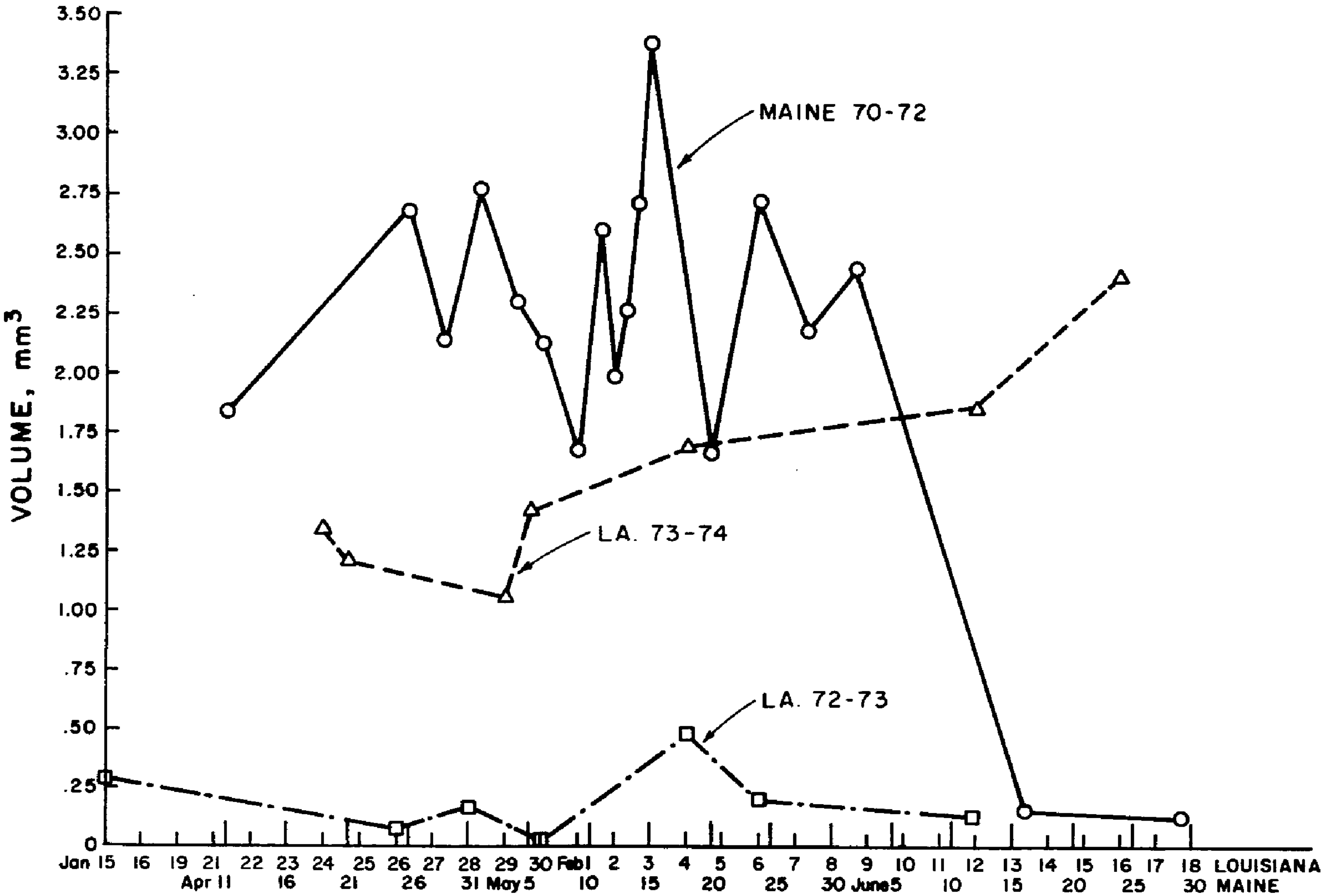
Source	Mean testes volume
Louisiana 1972-73	.2424 mm^3 [a]
Louisiana 1973-74	1.4204 mm^3
Maine 1970-72	1.9086 mm^3

[a] Significantly different from other two sources by means of t-test at p>.05.

In an effort to identify a cause for the differences of testes volumes between the two winters, certain environmental conditions were analyzed. Considerable research has been conducted on the relationships of environmental conditions and reproductive development in birds. Baker (1938) observed that "the main proximate causes of the breeding seasons of birds in nature are thought to be temperature and length of day in the boreal and temperate zones and rain or intensity of insolation near the equator."

Most workers have observed that photoperiods are more important than temperature for determining reproductive activity. Burger (1949) observed that testicular enlargement in wild starlings occurred at approximately the same rate during cold spring months as during warm spring months. Witschi (1935) noted that "prolonged Indian summers with sunny days extending until late November brought about precocious development of testes in free-living English Sparrows in Iowa." Kendeigh (1941) compared the reproductive activity of birds under temperatures of approximately 35°F with reproductive activity at higher temperatures and found no difference. Suomalainen (1937) found no difference in reproductive responses to light between one group of Great Tits (_Parus major_) kept at an average temperature of 1.9°C and another kept at 20°C.

Figure 53. A comparison of the volume of testes collected from woodcock during the spring months of 1970, 1971, and 1972 in Maine and from woodcock collected during the winters of 1972-73 and 1973-74 in Louisiana.


VOLUME, mm^3
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
MAINE 70-72
LA. 73-74
LA. 72-73
Jan 15 16 19 21 22 23 24 25 26 27 28 29 30 Feb1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 LOUISIANA
Apr 11 16 21 26 31 May 5 10 15 20 25 30 June 5 10 15 20 25 30 MAINE

Burger (1948) found that European Starlings (Sturnus vulgaris) kept under conditions of long days and 90°F to 100°F temperatures had testes far larger than birds kept under cooler, fluctuating temperatures. However, the warm conditions did not induce progressive spermatogenesis under conditions of shorter days. Epple et al. (1972) found that shorter days did not prevent the maturation of the testes of the Rufous-collared Sparrow (Zonotrichia capensis costaricensis) up to the formation of primary spermatocytes, but the final stages of spermatogenesis remained to be induced by longer days. Their experiments clearly showed the existence of photoperiodic testicular responses. Some authors [Jenner and Engels (1952) and Kirkpatrick and Leopold (1952)] have observed that the duration of the period of darkness is the controlling factor for testicular development, and if the period of darkness is long enough that gonadotropic activity does not occur. Jenner and Engles (1952) pointed out that testicular reactions are a function of the quantity of light in the form of intensity and time. Farner et al. (1953) observed that darkness was only minimally responsible for testicular activity and that short periods of light rather than long periods of darkness were responsible for testicular regression.

Regardless of the precise cause, obviously photoperiods and perhaps temperatures control testicular responses in birds. Temperatures and cloud coverages were obtained for the two winters during which woodcock testes were collected in Louisiana and these data are presented in Table 21. The winter of 1973-74 was somewhat warmer than the preceeding one and the degree of sky coverage was significantly less in 1973-74 than in 1972-73. Perhaps these climatic differences between years, particularly the quantity of light, were responsible for the advanced reproductive

Table 21. A comparison of the average temperature and daylight sky coverage for the two winters in which woodcock were collected in southeast Louisiana.

1972 - 1973

Month	Average Percent of Daylight Sky Coverage	Average Temperature (^{o}F)
November	72%	62.4^{o}
December	72	64.9
January	68	59.1
February	59	61.8
Means	67.7	62.05

1973 - 1974

Month	Average Percent of Daylight Sky Coverage	Average Temperature (^{o}F)
November	47%	68.2^{o}
December	45	64.9
January	80	69.1
February	49	67.4
Means	55.2 (1)	67.4

(1) Average percent daylight sky coverage significantly different by means of t-test at ($p < .05$).

state of woodcock collected in 1973-74 as compared to those collected in 1972-73...

Testes develpment related to migration

Relationships between migration and gonadal development have been studied by Rowan (1926, 1929, 1931, 1946). He found the intensity and timing of both spring and fall migrations to be affected by hormones secreted by the testes or ovaries (stimulated by the pituitary gland) and regression and recrudescence of the gonads to be caused by changes in quantities of light.

As pointed out in the section on local movements, the winter of 1973-74 was somewhat abnormal in that the peak numbers of woodcock observed in nocturnal fields occurred in late January and early February whereas the peak numbers in the two preceding winters occurred in mid-January. The warmer temperatures and longer periods of unobstructed light, which resulted in the advanced reproductive development, was in all likelihood also responsible for the delayed arrival and lower numbers of woodcock observed on the study areas.

Data collected for the winters of 1972-73 and 1973-74 suggest that breeding activity on the wintering range may be more intense during warmer, brighter winters. Also, migration to and from the wintering grounds may be affected by climatic conditions. Management policies, such as hunting seasons, perhaps should be evaluated with these seasonal variations in mind.

ADDITIONAL OBSERVATIONS

Having spent many hours in both nocturnal and diurnal habitat during the course of this study, I made several observations that may benefit future studies of this species.

During the 3 years of this study, I collected five injured woodcock from diurnal habitat. I shot three adult females and one immature male with twigs impaled in the upper parts of their bodies. All these wounds seemed to be rather old as no sign of fresh blood was present and the surrounding skin had healed. No substantial infection was evident around any of these wounds. I collected one adult male with the lower three-fourths of the bill severed. This bird weighed only 92 grams and seemed to be poorly nourished.

I attempted to monitor woodcock movements utilizing radio telemetry, but these attempts failed because of the inability of the equipment to emit and receive a signal at distances greater than one-half mile. Birds caught in their nocturnal habitat were equipped with a transmitter and when they flew to their diurnal habitat, the signal was lost. Before telemetry could be used as a monitoring instrument in the bottomland hardwood type of habitat in southeast Louisiana, equipment capable of producing and receiving stronger signals would have to be employed and aircraft surveillance would probably be necessary because ground travel through swamp type environments is limited.

I attempted, particularly when the study was initiated, to calculate the benefit of a dog for flushing woodcock in diurnal habitat.

I spent 32 hours hunting in diurnal habitat without dogs and observed 54 flushes. In this same area I spent 48 hours hunting with a pair of Brittany Spaniels and these efforts resulted in 116 flushes. Thus, the flush-per-hour ratio without dogs was 1.688 while the ratio with dogs was 2.417. On three occasions I witnessed an occurrence whereby a group of hunters walked through an area without dogs. Shortly thereafter another group of hunters went through the same area with dogs and flushed a relatively large number of woodcock.

Another interesting observation made during the course of collecting woodcock from diurnal cover was the low incidence of crippling loss. Of 462 woodcock collected in diurnal cover, I lost only 11 (2 percent). Four of these fell in creeks or bayous and were carried away by flowing water so that only seven (1 percent) were actually lost after being crippled. This crippling loss is very low compared to most game birds and it is, I believe, due to two factors. First, the woodcock has a very strong scent that allows dogs to locate it easily, and secondly this species is more easily killed than other game birds its size. Often, only one No. 8 shot pellet is sufficient to knock down a woodcock.

As previously mentioned, this bird has a very strong scent and is quite easily located by hunting dogs. However, I have seen several dogs that refused to pick up a woodcock after it had been shot. After questioning the owners of these dogs I found that all these dogs had been trained on quail and were used only intermittently for woodcock. I never witnessed a dog, which had been trained for hunting woodcock, that refused to pick up a shot woodcock.

I made several observations concerning capturing woodcock in nocturnal habitats. Having worked in nocturnal fields with approximately 25 workers, I found that those who wore glasses were not as successful at capturing woodcock at night as those who did not wear glasses. I also found that wearing rubberized rain gear on rainy nights reduced the number of birds caught, presumably because of the noise it made when the worker moved. I observed that the eye shine of woodcock varied considerably with time and distance even when the same spotlight was used. On damp, misty evenings the eye appeared more orange and glowing while on dry nights it appeared yellowish. Also, the intensity of the shine seemed to be inversely related to the distance from the bird. The closer the worker was to the woodcock the harder it was to see the eye. Finally, I was impressed with the apparent lack of predation on woodcock in nocturnal fields. On every trip to nocturnal habitats, a large number of potential predators such as skunks, raccoons, domestic cats, owls, and mink were observed, but I never observed any evidence of woodcock having been killed in these fields.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The specific findings have been summarized within each section, but some general conclusions and management implications warrant special mention.

Woodcock showed a definite tendency to associate themselves with environmental conditions that were not typical of the areas studied. Environmental conditions such as soil moisture, litter depth, overstory composition and density, understory plant communities, and understory densities were shown to be significantly different on sites utilized by woodcock as compared to random or typical sites. Although there was considerable variability for each of these factors between flushing sites, the resultant site "structure," which could be interpreted as the sum total of all these factors, was very similar. One factor considered indicative of this structure was the quantity of light or the amount of light reduction. I found that preferred habitats had to have the capability of reducing an average of 70 percent of the external light, regardless of the external light intensity. This reduction means that habitat variables such as overstory and understory speciation and densities must possess the diversity to allow substantial light penetration under low-light conditions and to restrict light penetration under bright light conditions. The findings of the eye analyses provided a morphological explanation for this phenomenon. The management implications of these findings include perhaps a modification of habitat structure in terms of diversity of densities rather than intensive management of certain plant species, which is now the typical management practice. Forestry practices such as prescribed burning and harvesting systems that favor natural regeneration in all likelihood benefit woodcock habitat by creating diversities of vegetative densities.

The importance of habitat was also emphasized in the food habits analyses portion of this study. Rather than show a specific requirement for a certain type of food, woodcock were found to be rather opportunistic feeders and utilized any food their immediate habitat contained. The feeding frequency data indicated that woodcock have a high energy requirement. The cyclicity of feeding illustrated the regularity with which woodcock feed. Two of their three feeding cycles occurred in diurnal habitats, thereby suggesting that occupancy of open fields at night may be for reasons other than those associated with feeding. With their capability for nocturnal vision, perhaps the occupancy of open fields at night is advantageous to escaping predation. Considering the strength of their scent, nocturnal occupancy of wooded areas would make woodcock particularly susceptible to predation by mammals such as skunks, mink, or bobcats.

Woodcock were shown to move south in response to cold periods and perhaps move north during warmer periods. Also, the intensity and timing of migrations may be predicated on climatic conditions, suggesting that habitats other than bottomland hardwoods may be important woodcock wintering grounds during certain times. More habitat work should be centered in the pine belts of the southeast United States and perhaps investigations into utilization of the coastal marshes should be undertaken.

The analyses of reproductive activity showed the incidence of nesting to be fairly common in north Louisiana. Research into the size of the resident population would be beneficial to management of this species. The frequency with which hunters kill female woodcock carrying eggs is rare, although this frequency seems to increase during the latter part of the hunting season. On the basis of the findings of this study; however, there seems to be no management need to shorten the hunting season in Louisiana. Testes development in males was shown to be correlated with climatic conditions and the degree of development could possibly be used as an indicator for predicting breeding dates and migrational trends.

Although no specific evidence exists to indicate a shortage of bottomland hardwood habitats in southeast Louisiana, the findings of this study suggest that several current land management practices may be leading to the decimation of wintering habitat as a whole. The possibility that woodcock make use of pinelands could conceivably affect woodcock habitat. The conversion of uneven-aged forests to even-aged forests or of mixed pine and hardwood areas to pure pine stands would act to the detriment of woodcock habitat by reducing the diversity of plant forms shown to be necessary for providing optimum light conditions. Clearing of bottomland hardwood areas for agricultural purposes is also detrimental to diurnal woodcock habitat because this practice tends to reduce vegetational diversity. Another land management practice common to many areas of southern Louisiana, which affects woodcock habitat, is the drainage of swamps and low areas for agricultural development. Glasgow (1958) observed that moist soil was a necessity for nocturnal feeding sites and this study demonstrated the need for diurnal habitats that have high soil moisture. Land drainage is acting to the detriment of both these habitat types.

LITERATURE CITED

Aldous, C. H. 1938. Woodcock management studies in Maine. Trans. N. Amer. Wildlife Conf. 4:437-441.

Aldous, S. E. 1944. A deer browse survey method. J. Mammal. 25:130-136.

Allen, G. M. 1925. Birds and their attributes. Marshall Jones Company, Boston. 368 pp.

Avery, T. E. 1967. Forest Measurements. McGraw-Hill, Inc., New York. 290 pp.

Baker, J. R. 1938. The relationship between latitude and breeding seasons in birds. Proc. Zool. Soc. London, 108 Series A:557-582.

Baker, W. L. 1972. Eastern forest insects. U.S.D.A., Forest Service Misc. Pub. 1175. 642 pp.

Beyer, O. E., A. Allison, and H. H. Kopman. 1908. List of birds of Louisiana. Auk 25:173-180.

Blankenship, L. H. 1957. Investigations of the American woodcock in Michigan. Michigan Conserv. Dept., Rept. 2123. 217 pp.

Britt, T. L. 1971. Studies of woodcock on the Louisiana wintering ground. M.S. Thesis. Louisiana State Univ., Baton Rouge. 105 pp.

Brunett, H. E. 1967. Establishment of browse. La. Pittman-Robertson Job Completion Rep. W-29-R-14, Job 8:20-22.

Burger, J. W. 1949. A review of experimental investigations on seasonal reproduction in birds. Wilson Bull. 61:211-230.

Carpenter, J. W. 1970. Food habits of the mourning dove in northwest Oklahoma. M.S. Thesis. Okla. State Univ., Stillwater. 67 pp.

Cobb, S. 1959. On the angle of the cerebral axis in the American woodcock. Auk 76(1):55-59.

Core, E. L. 1974. Red mulberry (*Morus rubra* L.). Pages 106-107 *in* Shrubs and vines for northeastern wildlife. U.S.D.A., Forest Service Report NE-9.

Dunford, R. D., and R. B. Owen, Jr. 1973. Summer behavior of immature radio-equipped woodcock in central Maine. J. Wildl. Manage. 37(4): 462-469.

Emlen, J. T. 1955. The study of behavior in birds. Page 167 in A. Wolfson. Recent studies in Avian Biology. Univ. of Illinois Press, Urbana.

Ensminger, A. B. 1954. Earthworm populations on wintering areas of the American woodcock in the vicinity of Baton Rouge, Louisiana. M.S. Thesis. Louisiana State Univ., Baton Rouge. 97 pp.

Epple, A., H. O. Gordon, D. S. Farner, and R. A. Lewis. 1972. The photoperiodic testicular response of a tropical finch (Zonotrichia capensis costaricensis). The Condor 74:1-4.

Evans, A. C., and W. J. McGuild. 1947. Studies on the relationships between earthworms and soil fertility. Ann. Appl. Biol. 34(3):307-330.

Farner, D. S., L. R. Mewaldt, and S. P. Irving. 1953. The roles of darkness and light in the activation of avian gonads. Science 118(3065): 351-352.

Fenneman, N. M. 1938. Physiography of the eastern United States. McGraw-Hill Inc., New York. 247 pp.

Fernald, M. L. 1950. Gray's manual of botany. American Book Co., New York. 1,632 pp.

Fisk, H. N. 1952. Geological investigation of the Atchafalaya Basin and the problem of Mississippi River diversion. U.S. Army Corps of Engineers, Miss. River Comm. (Vicksburg, Miss.), Vol. 1. 145 pp.

Glasgow, L. L. 1953. The American woodcock (Philohela minor) in Louisiana. Proc. S.E. Game Conf., Chattanooga, Tenn. 16 pp.

__________. 1956. A method of measuring wintering woodcock populations on nocturnal feeding sites in Louisiana. U.S. Fish and Wildlife Serv. Spec. Sci. Rept. Wildl. No. 31:7-10.

__________. 1958. Contributions to the knowledge of the ecology of the American Woodcock (Philohela minor), on the wintering range in Louisiana. Ph.D. Thesis. Texas A & M, College Station. 153 pp.

Goodrum P., and V. Reid. 1952. Wintering woodcock populations in west-central Louisiana. U.S. Fish and Wildlife Serv. Spec. Sci. Rept. Wildl. No. 14:10-14.

Halls, L. K., and P. D. Goodrum. 1961. Japanese honeysuckle (Lonicera japonica). Pages 38-40 in Deer browse plants of southern forests. U.S. For. Serv. South. and Southeast. For. Expt. Stas.

Handley, W. R. C. 1954. Mull and mor information in relation to forest soils. Forestry Can. Bull. No. 23. Her Majesty's Stationery Office, London. 14 pp.

Harmon, W. J. 1952. A taxonomic survey of the earthworms of Lincoln Parish, Louisiana. Proc. La. Acad. of Scien. 15:19-25.

Jackson, L. W. 1974. Honeysuckles. Pages 71-82 in Shrubs and vines for northeastern wildlife. U.S.D.A., Forest Service Report NE-9.

Jenner, C. E., and W. L. Engels. 1952. The significance of the dark period in the photoperiodic response of male Juncos and White-throated Sparrows. Biol. Bull. 103(3):345-355.

Kendeigh, S. C. 1941. Length of day and energy requirements for gonad development and egg laying requirements in birds. Ecology 22:237-245.

Kinitzsky, E. L., and F. L. Smith. 1969. Geology of the backswamp deposits in the Atchafalaya Basin, Louisiana. U.S. Army Corps of Engineers Waterway Exp. Sta. Tech. Rept. S-69-8, Vicksburg, Miss.

Kirkpatrick, C. M., and A. C. Leopold. 1952. The role of darkness in sexual activity of the quail. Science 116(3011):280-282.

Kletzly, R. C., and J. Rieffenberger. 1967. Woodcock banding studies in West Virginia's Canaan Valley. Pages 31-33 in W. H. Goudy. Woodcock research and management. 1966. U.S. Fish and Wildlife Serv. Spec. Sci. Rept. Wildl. No. 101.

Knight, J. A. 1944. Woodcock. Alfred Knopf, New York. 161 pp.

Krohn, W. B. 1970. Woodcock feeding habits as related to summer field usage in central Maine. J. Wildl. Manage. 34(4):769-775.

Liscinsky, S. A. 1956. Semi-annual progress report Pittman-Robertson research and development projects. Pa. Game Comm. 9:48-54.

______________. 1964. The Pennsylvania woodcock study. Pa. Game News October 35(10):14-17.

______________. 1972. The Pennsylvania woodcock management study. Pa. Game Comm. Res. Bull. 171. 93 pp.

Lowery, G. H., Jr. 1974. Louisiana birds. La. State Univ. Press, Baton Rouge. 651 pp.

Lynch, J. J. 1952. Woodcock in south Louisiana during the freeze of January-February, 1951. U.S. Fish and Wildlife Serv. Spec. Sci. Rept. Wildl. No. 14:3-9.

Lytle, S. A. 1968. The morphological characteristics and relief relationships of representative soils in Louisiana. Bull. 631. La. State Univ. Press, Baton Rouge. 23 pp.

Maisenhelder, L. C. 1958. Understory plants of bottomland forests. U.S.D.A., Forest Service South. For. Exp. Sta. Occ. Paper 165. 40 pp.

Marshall, W. H. 1958. Woodcock singing grounds at the Cloquet Experimental Forest, 1947-1956. St. Paul, Minnesota Agr. Exp. Sta. Sci. Journal Series No. 3859:296-305.

Martin, F. W. 1962. Woodcock status report, 1962. U.S. Fish and Wildlife Serv. Spec. Sci. Rept. Wildl. No. 69. 36 pp.

___________. 1964. Woodcock age and sex determination from wings. J. Wildl. Manage. 28(2):287-293.

Martin, A. C., and W. D. Barkley. 1973. Seed identification manual. Univ. of Calif. Press, Berkeley. 221 pp.

Maxfield, H. K. 1961. A vegetational analysis of fifty singing grounds in central Massachusetts. Unpubl. M.S. Thesis. Univ. of Mass, Amherst. 27 pp.

McGuild, W. J. L. 1951. The distribution and population density of earthworms (Lumbricidae) in Scottish pasture fields. J. Anim. Ecol. 20(1):88-97.

McIlhenny, E. A. 1940. Effect of excessive cold on birds in southern Louisiana. Auk 57:408-410.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American Woodcock. Maine Coop. Wildl. Res. Unit, Univ. of Maine, Orono. 201 pp.

Merovka, L. J. 1939. The woodcock in Louisiana. Louisiana Conser. Review 8(4):10-14.

Miller, D. R. 1957. Soil types and earthworm abundance in woodcock habitat in central Pennsylvania. M.S. Thesis. Dept. of Zoology and Entomology. Pa. State Univ., University Park. 69 pp.

Moore, D. M. 1961. Rubus spp. Pages 56-57 in Deer browse plants of southern forests. U.S.D.A., Forest Service South. and Southeast. For. Expt. Stas.

Murchie, W. R. 1954. Natural history study on the earthworms of Michigan. Ph.D. Dissertation. Univ. of Michigan, Ann Arbor. 296 pp.

Musser, E. G. 1942. Analysis of selected woodcock habitat of the Pennsylvania Allegheny Mountains section. Report of the Penn. Coop. Wildl. Res. Unit. 17 pp.

Norris, R. T. 1941. Woodcock wintering ground studies in Louisiana, Dec. 1940-Feb. 1941. Report to U.S. Fish and Wildlife Serv. 45 pp.

Olson, H. W. 1928. The earthworms of Ohio. Ohio Biol. Surv. Bull. 17(4):47-90.

Owens, J. V. 1967. Food habits of the common snipe (Capella gallinageo delicata) in the pastures of south-central Louisiana. Unpub. M.S. Thesis. Louisiana State Univ., Baton Rouge. 106 pp.

Pettingill, O. S. 1936. The American woodcock (Philohela minor Gmelin) Mem. Boston Soc. Nat. Hist. 9:167-391. 10 pp.

Pettingill, O. S., Jr. 1970. Ornithology in laboratory and field. Burgess Pub. Co., Minneapolis, Minn. 524 pp.

Pitelka, F. A. 1943. Territorality, display, and certain ecological relations of the American woodcock. Wilson Bull. 55(2):88-114.

Pumphrey, R. J. 1961. Sensory organs: vision. Pages 55-68 in A. J. Marshall, editor. Biology and comparative physiology of birds. Vol. II. Academic Press, New York.

Putnam, J. A., G. M. Furnival, and J. S. McKnight. 1960. Management and inventory of southern hardwoods. U.S.D.A., Forest Service Handbook No. 181. 102 pp.

Radford, A. E., H. E. Ahles, and C. R. Bell. 1968. Manual of the vascular flora of the Carolinas. University of North Carolina Press, Chapel Hill. 1,183 pp.

Reardon, J. D. 1950. Woodcock utilization of improved covers in eastern Maine. M.S. Thesis. Univ. of Maine, Orono. 75 pp.

Reid, V., and P. Goodrum. 1953. Wintering woodcock populations in west-central Louisiana, 1951-52. U.S. Fish and Wildl. Serv. Spec. Sci. Rept. Wildl. No. 18:4-12.

________________________. 1954. Observations of woodcock breeding in certain southeastern states. U.S. Fish and Wildl. Serv. Spec. Sci. Rept. Wildl. No. 24:17-18.

________________________. 1955. Wintering woodcock populations in west-central Louisiana, 1953-54. U.S. Fish and Wildl. Serv. Spec. Sci. Rept. Wildl. No. 28:7-11.

Rowan, W. 1926. On photoperiodism, reproductive periodicity, and the annual migrations of birds and certain fishes. Proc. Boston Soc. Nat. Hist. 38:147-189.

________. 1929. Experiments in bird migration, I. Manipulation of the reproductive cycle: Seasonal histological changes in the gonads. Proc. Boston Soc. Nat. Hist. 39:151-208.

________. 1931. The riddle of migration. Williams and Wilkins Pub. Co., Baltimore. 151 pp.

________. 1946. Experiments in bird migrations. Trans. Royal Soc. of Canada, 3rd ser., Section V, 40:123-135.

Saucier, R. T. 1974. Quaternary geology of the lower Mississippi Valley Arkansas archeological survey. Publications on Archeology Research, Series No. 6. Univ. of Ark. Museum, Fayatteville.

Sharp, W. M. 1974. Ecology of shrubs and vines. Pages 2-6 in Shrubs and vines for northeastern wildlife. U.S.D.A., Forest Service Report NE-9.

Sheldon, W. H. 1961. Summer crepuscular flights of American woodcock in central Massachusetts. Wilson Bull. 73(2):126-139.

____________. 1967. The book of the American woodcock. Univ. of Mass. Press, Amherst. 227 pp.

Smith, R. L. 1974. Greenbriers. Pages 54-59 in Shrubs and vines for northeastern wildlife. U.S.D.A., Forest Service Report NE-9.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. Iowa State Univ. Press, Ames. 593 pp.

Sperry, C. C. 1940. Food habits of a group of shorebirds: woodcock, snipe, knot and dowitcher. U.S. Biol. Surv. Wildl. Res. Bull. I. 37 pp.

Studholme, A. T., and R. T. Norris. 1942. Breeding woodcock populations. Auk 59:229-233.

Suomalainen, H. 1937. The effect of temperature on the sexual activity of non-migratory birds, stimulated by artificial light. Ornis Fennica 14:108-112.

Thompson, D. Q. 1965. Unusual choice of cover by woodcock. N.Y. Fish and Game Journ. 12(2):241-242.

U.S. Department of Commerce. 1970-73. Local climatological data. Annual summary with comparative data, 1970, 1971, 1972, 1973. Baton Rouge, La.

Van Pelt, A. 1951. All outdoors. Times Picayune, New Orleans. Jan. 21-27, 1951.

Walls, G. L. 1942. The vertebrate eye and its adaptive radiation. Cranbrook Inst. Sci., Bloomfield Hills. 785 pp.

Waterman, A. J. 1971. Chordate structure and function. Macmillan Co., New York. 587 pp.

Weeden, R. B. 1955. Cover requirements of breeding woodcock in central Maine. M.S. Thesis. Univ. of Maine, Orono. 100 pp.

Witschi, E. 1935. Seasonal sex characters in birds and their hormonal control. Wilson Bull. 67:177-188.

Yancey, R. K. 1969. The vanishing delta hardwoods: Their wildlife resources. Governors Seminar on Miss. Hardwoods. Little Rock, Ark. 18 pp.

APPENDIX

Table 22. Plants sampled from 202 woodcock flushing sites on three bottomland hardwood study areas in south-central Louisiana.

Common name	Scientific name
Dewberry and Blackberry	*Rubus* spp.
Grasses	Poaceae (family)
Oaks	*Quercus* spp.
Switch-cane	*Arundinaria gigantea*
Rattan-vine[a/]	*Berchemia scandens*
Greenbrier	*Smilax* spp.
Planer-tree	*Planera aquatica*
Butterweed	*Senecio glabellus*
Elderberry	*Sambucus canadensis*
Cross-vine	*Anisostichus capreolata*
Sweetgum	*Liquidambar styraciflua*
Sugarberry	*Celtis laevigata*
Aster	*Aster* spp.
Honeylocust	*Gleditsia triacanthos*
Green ash	*Fraxinus pennsylvanica*
Japanese honeysuckle	*Lonicera japonica*
Spicebush	*Lindera benzoin*
Poison ivy	*Rhus radicans*
Swamp dogwood[a/]	*Cornus drummondii*
Boxelder	*Acer negundo*
Goldenrod	*Solidago* spp.
Gum	*Nyssa* sp.
Christmas fern	*Polystichum acrostichoides*
Hickories	*Carya* spp.

Table 22. (continued)

Common name	Scientific name
Vetch	*Vicia* spp.
Red maple	*Acer rubrum* var. *drummondii*
Smartweed	*Polygonum* spp.
Violet	*Viola affinis*
Deciduous holly	*Ilex decidua*
Palmetto	*Sabal minor*
Hawthorn	*Crataegus* spp.
Ironwood	*Carpinus caroliniana*
Pennywort	*Hydrocotyl* spp.
Dayflower	*Commelina* sp.
Virginia creeper	*Parthenocissus quinquefolia*
Grape	*Vitis* spp.
Sedges	Cyperaceae (family)
Oplismenus	*Oplismenus setarius*
Spilanthes	*Spilanthes americana*
Basswood	*Tilia caroliniana*
Ladies'-eardrops	*Brunnichia cirrhosa*
Red-berried moonseed[a]	*Cocculus carolinus*
Pepper-vine	*Ampelopsis arborea*
Trumpet-creeper[a]	*Campsis radicans*
Buttercup	*Ranunculus* spp.
Geum	*Geum canadense*

[a] From Fernald (1950).

VITA

James M. Dyer was born to Mr. and Mrs. James E. Dyer on May 22, 1946 in El Reno, Oklahoma. He attended school there and graduated from El Reno High School in 1964.

He graduated from Oklahoma State University in 1969 with a Bachelor of Science degree in zoology. From 1969 to 1971 he did graduate work at Oklahoma State University and received a Master of Science degree in Wildlife Ecology.

He initiated his Ph.D. work at Louisiana State University in Baton Rouge, Louisiana, in 1971 and he is now a candidate for that degree.

EXAMINATION AND THESIS REPORT

Candidate: James Marshall Dyer

Major Field: Forestry

Title of Thesis: An Evaluation of Diurnal Habitat Requirements for the American Woodcock (Philohela minor Gmelin) in Southern Louisiana

Approved:

Robert B. Hamilton

Major Professor and Chairman

James R. Traynham

Dean of the Graduate School

EXAMINING COMMITTEE:

Leslie L. Glasgow

George H. Lowery, Jr.

Bart A. Thielges

Robert J. Chabreck

Date of Examination:

March 25, 1976

XUM